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Life History and Composition of the Soybean Plant

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LIFE HISTORY AND COMPOSITION OF THE SOYBEAN PLANT

INTRODUCTION

The soybean is the most important annual legume crop of Ohio. Since it grows comparatively well on acid soils and on those of low fertility, it has won an important place in the agriculture of the State. Although of comparatively recent introduction, its use has grown rapidly. This is evidenced by the increase in the acreage of the crop within the last decade, an increase which is surpassed by sweet clover alone. In 1920, 8,000 acres of soybeans were reported in Ohio and 190,000 acres in the United States (24). In 1929, the Ohio acreage had reached 180,000 and the United States' 3,190,000 (23), an increase of over twenty-fold in Ohio and of over ten-fold in the country at large. With the development of the commercial uses of the crop, it is conceivable that the soybean will fill a very large place in American agriculture.

As with any new crop, there has been much to learn regarding its culture. The aim of Part I of the present work has been twofold; first, a theoretical study of the effects of rate and date of sowing on behavior, and second, an outgrowth of the first—a life history study. Part II is a study of the yield and composition of the soybean plant from the stage of blooming to maturity. The content and movement of mineral matter and nitrogen in the plant parts are pointed out.

PART I.—INFLUENCE OF RATE AND DATE OF PLANTING ON GROWTH AND COMPOSITION

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HISTORY OF THE PROJECT AND METHODS USED

Soil types.—All studies reported in Part 1 were made on the farm of the Ohio State University, at Columbus. The soil varies from the light-colored, Miami silt loam and silty clay loam to the brown, Brookston silty clay loam and the deep, dark, Clyde silty clay loam (5). An effort was made each year to conduct the experiment entirely on a single soil type or on two closely related types.

Plan of experiment.—The project was started in 1922 with the Manchu and Peking varieties.

Manchu, an important seed variety in Ohio, is early, maturing in about 135 days at Columbus; it has a medium-large, yellow seed with a characteristic black hilum. Peking is a later variety, having a very small black seed and maturing in about 145 days at Columbus. It is a very erect-growing variety used for hay and planted with corn for silage. Thus, this choice of varieties represented early and late sorts, with large and small seed, grown for seed and for hay.

The seeds were planted with an accurate garden drill at three different rates in quadruplicated plots of five rows, 16 feet long and 28 inches apart. The three rates of planting employed were: thick, plants ¾ to one inch apart; medium, plants 3½ inches apart; thin, plants 8 inches apart. These rates represented two extreme rates and a medium, or normal, rate. For the thick rate the drill was set to sow as thickly as possible without wasting seed; the beans were dropped every ¾ inch, or slightly less. These thick rows were not thinned. Because of a lower mortality in the Peking, the resulting stand of this variety was slightly thicker than that of Manchu. To obtain the desired spacing in the medium and thin plantings, seeds were sown at the same rate for both and the seedlings thinned to the stand desired.

The following tabulation gives the approximate amounts of seed required per acre for each rate of Manchu and Peking:

Variety	Rate	Spacing	Pounds of seed
		Inches	
Manchu	Thick	¾ to 1	120 (actually used)
	Medium	3½	31*
	Thin	8	15*
Peking	Thick	¾ to 1	60 (actually used)
	Medium	3½	12*
	Thin	8	5.5*

*Calculated from thinned stand, assuming same percentage of mortality observed in thick planting.

Plantings were made every 2 weeks, beginning with the first of May and continuing until the first of August. The second row of each plot was cut for hay when the pods were full grown and the beans about one-fourth grown (28). The fourth row of each plot was harvested for seed when ripe, leaving the first, third, and fifth as border rows. Notes were taken on height and habit of growth as affected by rate of planting.

Pigeons destroyed some of the sowings in 1922; thus, the results are somewhat deficient for that year and are not included in the present paper.

In 1923, the first planting was made April 19, and subsequent plantings were made every 2 weeks from May first to August first, as in 1922. The varieties, rates, methods of sowing, thinning, and harvesting, and number of replications were similar to those used in 1922, except that two rows were harvested for seed. In addition, a series of plots approximately 8 feet wide, with rows 7 inches apart, was included to ascertain the effects of the various rates of sowing in the so-called "solid" sowing where the plants had competition on all sides.

In 1924, the first planting was made April 14, the subsequent ones as in previous years. Frost occurred on May 22, injuring the first seeding materially. The plan of planting differed this year in that from five to 11 rows were used in each plot, depending on the date of sowing—the later sown plots having fewer rows. This change was made to facilitate harvesting one row from each plot at 10-day intervals, which was done after June 26. The plants were weighed green and again after becoming air-dry.

Preliminary root studies were also begun in 1924. Roots of mature, or nearly mature, plants were dug by making an excavation beside the plant and digging out the separate roots with a hand awl or ice-pick. It was found difficult to follow the fine, threadlike roots, but a fair idea of the extent of the root systems was obtained.

In 1925, the plantings were made April 10, April 15, and every 15 days thereafter, as in previous years. This year the length of row was reduced from 16 to 12 feet. Other methods used were much the same as those of 1924. Harvesting was begun earlier in the season, however, to obtain a more complete picture of the development of the different sowings. Frosts occurred on May 25 and 26, which froze corn on adjacent fields but injured the beans little, if any.

Root studies were made in numerous plantings. Beginning at 12 days after planting, harvests of tops and roots were made of the June 15th planting and at 10-day intervals thereafter. Roots were dug from other sowings also to study the rapidity and extent of growth.

In 1926, plantings were made on April 10, April 20, May 1, and at 2-week intervals thereafter until August 1.

In sowing and harvesting, the procedure was essentially the same as in 1925. Root studies were conducted on a more elaborate scale than before. In order to make it possible to wash the roots out and to use undisturbed soil, the following procedure was employed: Eighteen bottomless "cans" of galvanized "Armco" iron, painted inside with asphalt paint, were sunk about columns of undisturbed soil. These cans varied in depth from about 16 inches to 3 feet, the shallower cans being used for the early harvests. After the "cans" were in place, the space surrounding them was filled with soil which was well packed. Manchu and Peking soybeans were planted in the cans on May 20. Nine "cans" were used for each variety. The rows were planted across the center of each container, transversing its 12-inch dimension, as well as the space between cans. Rows were also planted at a distance of 28 inches on either side of this row across the "can", and in this way field conditions were approximated.

The foregoing plantings were made on a deep, black, Clyde silty clay loam. In order to study the effect of soil type on the root systems of the two varieties, other "cans" were placed in a typical Miami silty clay loam. This is a brownish-gray soil with a heavy layer at a depth of from 18 to 24 inches.

The "cans" with the enclosed soil and plants were removed at 15-day intervals, and the soil washed from the roots. From the root studies made in 1924 and 1925, it was known that the roots of the soybeans would go deeper than the deepest can (3 feet). But these previous studies had also shown that the main central root is usually the only one that grows below this depth, and that these main central roots could be followed down and taken out fairly easily by digging and using a sharp awl or similar implement; so, this method was used. An enlarged can similar to that used by Weaver et al. (26) would have been ideal had one used filled soil. The object, however, was to leave the soil profile undisturbed.

Previous work had also indicated the size of the can needed. The spread of roots in 28-inch rows had been found to be about 30 inches. Obviously, cans 30 inches square would have given the roots a freer growth, but they would have been very difficult to handle.

The cans and enclosed soil column were removed by tipping them on to a platform lowered into an excavation made beside the can and lifting them out with a chain hoist attached to a derrick. As the cans were tipped, the columns of soil broke rather cleanly at the base of the can. After being lifted out, the cans were transferred on a stoneboat to the place of washing. Because of the density of the sub-soil and the delicate nature of the roots, washing was not accomplished without some root breakage. Where possible these broken portions were labeled and replaced for photographing. All pieces of root were saved for weighing. In all harvests but one, the main roots extending below the block of earth removed were followed down with an awl and were easily taken out. At the harvest made September 8, for some reason, it was impossible to find the main roots below the can. The pictures (Figure 12) of the roots harvested on this date show only the upper portions of the root systems.

Weather conditions hampered the last harvest of mature plants. Continued heavy rains filled the excavations, preventing work until the plants were over-ripe.

In 1927 the planting dates, rates, and procedure were the same as in 1926, except that no root studies were made and harvests were made only at the hay stage and at maturity. Because of poor seed, the July 1st planting of Manchu failed, and, due to a miscarriage of plans, the July 15th plantings were not thinned.

Inoculation.—As all soil areas used for the experiment had recently grown well-inoculated soybeans, no artificial inoculation was used.

Method of obtaining root yields.—Obviously, enough roots for direct quantitative determination of yield could not readily be obtained by the laborious method of harvesting roots described above. Consequently, an indirect method of obtaining root yields was used. The percentage of root weight to top weight was determined for the plants grown in the soil cans. Roots and tops were separated at the soil surface line. This percentage figure applied to acre yields of tops from adjacent replicated rows was assumed to give the acre yields of roots. Doubtless, this method is subject to error, but it is probably more accurate than direct methods of harvesting root systems in which the entire root system is not obtained. Yields of roots have been computed for 1925 and 1926 only, since the root studies of 1924 were preliminary.

Yields of pods and beans.—Yield determinations of the pods were begun as soon as they were large enough to be picked and separated from the stems satisfactorily. The yields of beans were obtained on all harvests made after the beans had become large enough to thresh.

Percentages and yields of the various plant parts.—The percentages of stems and leaves were determined on all the crops, except that of 1927, by carefully separating the leaves and their petioles from the stems, weighing each separately. Determinations of all plant parts (stems, leaves, pods, seeds, and roots) are reported for 1925 and 1926 only, as root studies were made most fully in these 2 years. The data for each year are reported separately. Variation of harvest dates in the different years makes averaging unsatisfactory and it has the further disadvantage of obscuring seasonal differences.

Reliability of data.—All forage and seed yield determinations are based on four replications, except the first sowings in 1925 and 1926, where two and three replications were used. In the tables and graphs where the three rates have been averaged, each yield is the average of 12 replications.

DATA AND DISCUSSION

The effects of rate of planting on height and habit of growth.—Rate of sowing produced a noticeable, but rather unimportant, effect on the height and habit of growth. The thickly-sown soybeans at first grew in height more rapidly than the medium- or thinly-planted ones, and the medium-planted more rapidly than the thinly-planted, so that about 5 weeks after planting there was a marked difference in the height, which continued nearly all season.

TABLE 1.—Heights of Soybean Varieties Sown at Three Rates

Year and dates of record	Sown May 15			Dates of record	Sown June 15		
	Rates sown				Rates sown		
	Thick* Inches	Medium† Inches	Thin‡ Inches		Thick* Inches	Medium† Inches	Thin‡ Inches
			Manchu				
1922							
July 12	25	22	20	Aug. 2	13	11	10
Aug. 2	35	33	32	Sept. 8	27	26	26
1923							
June 23	16	14	13	July 26	28	27	25
July 26	41	40	38	Sept. 10	27	25	24
1924							
Aug. 9	41	40	41	Aug. 9	24	24	23
1925							
July 2	18	17	15	July 31	18	17	14
Aug. 14	36	34	32	Sept. 10	33	32	29
1926							
June 29	17	16	15	July 10	14	13	11
July 30	31	29	27	Aug. 31	34	34	32
			Peking				
1922							
June 22	13	10	10	Aug. 2	10	9	8
Sept. 8	29	27	24	Sept. 8	30	27	25
1923							
June 23	15	13	12	July 26	14	13	12
July 26	29	30	27	Sept. 10	16	13	12
1924							
Aug. 9	34	34	31	Aug. 9	24	23	23
1925							
June 26	12	11	9	July 31	15	13	14
Aug. 14	36	33	32	Sept. 10	32	32	29
1926							
June 29	13	13	12	July 21	17	14	14
Aug. 20	36	35	34	Sept. 15	37	37	35

*Thick rate—Plants 1 inch apart.
†Medium rate—Plants 3½ inches apart.
‡Thin rate—Plants 8 inches apart.

(See Table 1). The thicker plantings also appeared more vigorous in the early stages of growth. Lipman et al. (15), in studying the influence of thickness of planting on protein content of soybeans, made similar observations and suggested "that in associations of numbers there is increased or intensified utilization of atmospheric nitrogen". The writer has observed in preliminary experiments in the greenhouse that a reduction of light from lateral sources in the thick plantings results in an increased height of the plant.

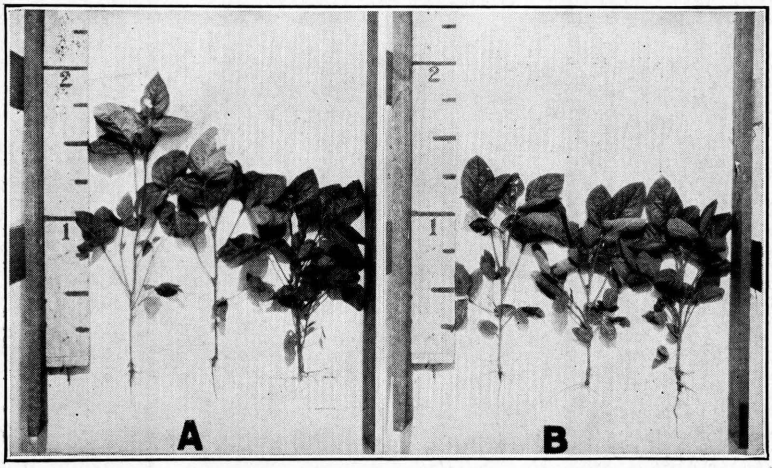

Fig. 1.—Soybeans planted at the three rates. From left to right, thick, medium, thin.
A. Manchu B. Peking

An expected difference in habit of growth accompanied this difference in height. The thinner rates of sowing produced more stocky and erect plants. Figure 1 brings out the differences in the height and the habit of growth of the plants from the different planting rates.

The effect of the rate of planting on relative proportion of leaf and stem.—A question often asked by soybean growers is whether or not the rate of planting influences the relative proportion of stem and leaf in the plant. Determination of the percentages of leaves in the total weight of stems and leaves were made, as previously described, on all crops after 1922. A part of these results is given in Table 2. Evidently, planting at the different rates did not change the leaf-stem proportion. In some of the later harvests it seems that there was a lower proportion of leaf to stem in the thick plantings than in the medium or thin. This is accounted for by the fact that the thick rows began to lose leaves sooner than the medium or thin rows.

A point closely related to this is the relative proportion of edible stems. Observations of the plants from the different planting rates lead to the belief that there is a higher percentage of edible stems in the thick plantings than in the medium or thin plantings (See Fig. 1). The Illinois Experiment Station (1) reports that dairy cows ate a higher percentage of soybean hay with fine stems produced by thick planting rates than of that with coarser stems produced by thin planting rates.

TABLE 2.—Proportion of Leaves to the Combined Weight of Leaves and Stems of Soybeans Sown at Different Rates

Date sown	Date harvested	Manchu			Peking		
		Planting rates			Planting rates		
		Thick Pct.	Medium Pct.	Thin Pct.	Thick Pct.	Medium Pct.	Thin Pct
1923							
May 15	At hay stage*	73	73	73	70	69	69
June 1	At hay stage	76	78	75	68	69	71
June 15	At hay stage	73	73	71	68	69	71
Average		74	75	73	69	69	70
1924							
May 1	June 26	66	77	78	78	78	82
May 15	July 30	56	58	56	61	69	67
June 1	Aug. 8	57	56	57	61	63	65
June 15	Aug. 8	65	81	63	74	72	74
July 15	Aug. 29	78	77	81	82	83	85
Aug. 1	Sept. 13	77	80	83	85	88	87
Aug. 1	Oct. 11	77	78	81	77	80	81
Average		68	72	71	74	76	77
1925							
May 15	July 1	69	76	80	74	78	70
	July 22	59	58	63	70	71	69
	Aug. 1	58	61	64	68	67	70
	Aug. 20	60	63	67	63	65	66
	Aug. 31	55	62	50	58	60	61
	Sept. 21	36	34	34	55	55	56
Average		57	57	61	65	65	66
1926							
May 15	July 9	66	66	74	71	72	77
	July 20	56	59	63	60	63	67
	July 20	54	52	54	62	60	66
	Aug. 10	57	55	55	61	64	66
	Aug. 31	57	54	60	....	....	....
	Sept. 10	53	58	57	....	....	....
Average		57	57	61	....	....	....

*Pods formed, seeds beginning to form.

The effect of rate of planting on the content of nitrogen.—Data bearing on this question are presented in Table 14. There appear to be no consistent differences in the nitrogen content of the plants from the different rates of planting.

The effect of rate of planting on the amount of fiber.—There is a general belief that the coarser plants from the thin planting rates contain more fiber and are consequently lower in feeding value. Reference to Table 3 shows that there is no significant difference in the percentage of fiber in either pods, leaves, or stems of the plants sown at the different rates.

TABLE 3.—Feed Constituents of Soybeans

Sown at different rates, May 15, 1926 and harvested on August 31*

Plant part	Manchu			Peking	
	Thick Per cent	Medium Per cent	Thin Per cent	Medium Per cent	Thin Per cent
Protein					
Stems	15.0	14.2	13.7	9.7	11.0
Leaves	21.1	20.3	21.7	19.1	20.3
Pods and beans	27.3	24.7	26.3	22.3	22.7
Total tops	21.3	19.9	20.8	15.3	16.5
Fiber					
Stems	48.7	46.4	46.5	49.4	44.6
Leaves	17.5	18.2	15.2	22.8	20.4
Pods and beans	21.1	22.7	22.1	24.3	20.2
Total tops	27.8	27.9	26.6	33.8	30.3
Ash					
Stems	5.6	5.4	5.2	6.6	7.1
Leaves	16.5	14.6	13.0	13.8	13.4
Pods and beans	7.4	8.7	7.6	9.2	10.1
Total tops	10.4	10.0	9.0	10.6	10.6
Ether extract					
Stems	.7	.7	.8	.6	.8
Leaves	2.5	2.3	2.3	1.6	2.4
Pods and beans	4.2	4.4	4.1	1.8	4.0
Total tops	2.5	2.5	2.4	1.2	1.8
Nitrogen-free extract					
Stems	30.1	33.2	33.8	33.8	36.5
Leaves	42.5	44.8	47.8	42.7	43.5
Pods and beans	40.1	39.5	39.9	42.5	43.0
Total tops	38.1	39.7	41.2	38.9	40.5

*Hay stage of Manchu.

In this table are also given the contents of crude protein, ash, fat, and nitrogen-free extract. There is no significant difference in the percentage of any of these constituents.

The effect of rate of planting on the yield of forage.—By the yield of forage is meant the yield of air-dry hay at what was considered the best hay stage; i. e., the majority of pods full size and the beans about one-fourth grown. Work of Willard (28) had indicated that this is the best stage at which to cut soybeans for forage.

Table 4 gives the average yields of forage from the two varieties for the 5-year period (1923-1927). The thickest rate of planting produced the highest yields of forage in both varieties. In general, the different rates of planting have produced smaller differences in the forage yields of Peking than of Manchu. Manchu planted May 15 at the thick rate produced, as a 5-year average, nearly 900 pounds per acre more than at the medium rate; whereas Peking at the thick rate produced less than 500 pounds more than at the medium rate. This relative difference in yield was maintained through the season for the different rates of planting and also for the different dates of planting.

TABLE 4.—Forage Yields of Soybeans Sown at Different Rates and Dates

5-year average, 1923 to 1927, inclusive, except where noted

(Air-dry basis)

Dates sown	Manchu				Peking			
	Rates sown				Rates sown			
	Thick	Medium	Thin	Average	Thick	Medium	Thin	Average
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
April 10	4227†	3942†	3386†	3852†	4244†	3737*	3723*	3901*
April 15-20	4813	4448	3902	4288	4459	4181	3938	4192
May 1............	5179	4416	4027	4541	5443	5091	4823	5119
May 15............	5121	4252	3706	4360	5357	4906	4444	4902
June 1............	4772	4115	3865	4251	4800	4293	3938	4344
June 15............	4259	3532	2843	3545	4153	3626	3333	3704
July 1............	3464‡	3001‡	2754‡	3073‡	3669‡	2979‡	2775‡	3141‡
July 15............	2347	2077	1806	2077	2801	2481	2208	2497
Aug. 1............	1537	1138	821	1165	1295	853	736	961
Av. of all dates....	3969	3436	3012	....	4025	3572	3435	....

*2-year average.
†3-year average.
‡All rates 4-year average from this date on.

A wide variation in seed efficiency is evident when the yield of forage per pound of seed is computed, as shown in the following tabulation:

Pounds of Forage Produced From One Pound of Seed

	Thick rate	Medium rate	Thin rate
Manchu	43	137	247
Peking	89	408	808

The above summary was computed from the 5-year average of the yields of the May 15 plantings (Table 4) and the amount of seed used given in the table on page 4.

To ascertain whether or not the rate of planting would have the same effect when the rows were planted close together and competition thus increased, so-called "solid" plantings (rows 7 inches apart) were made in 1923 and 1926. Table 5 gives the yields produced. Evidently, maximum yields of seed are produced at a lower rate of planting per unit length of row in solid than in row plantings.

TABLE 5.—Yield of Soybeans Planted in Rows 7 Inches Apart

Year	Variety	Seed per acre			Forage air-dry per acre		
		Rates sown			Rates sown		
		Thick Bu.	Medium Bu.	Thin Bu.	Thick Lb.	Medium Lb.	Thin Lb.
1923	Manchu	40.1	40.4	38.3	....	....	....
	Peking	16.9	20.8	25.7	....	....	....
	Midwest.....	20.7	21.4	19.3	....	....	....
1926	Manchu	25.6	25.3	9.4	5820	4995	3204
	Peking	26.5	26.6	20.2	6554	5694	3842

The effect of rate of planting on the yields of seed.—The effect of the different rates of planting on yields of seed is somewhat different from the effect on yields of forage. (See Table 6). It will be noted that, whereas the yields of forage from the thick rate are much larger than from the medium rate, the yields of seed from the thick rate are only slightly larger than those from the medium rate. This is more apparent when the net yields of seed are considered, as in Table 7. In the production of seed the varieties appear less regular in behavior than in the production of forage. This may be explained partly by the fact that only 4 years' yields of seed are averaged and partly by unseasonably dry weather in 1925 and 1926 which not only reduced yields, but emphasized soil differences and thereby increased experimental error.

PRACTICAL CONSIDERATIONS

Although the present experiment was not planned to determine definite, optimum rates of planting, certain practical considerations are of interest. It appears from the results reported above that a high rate of sowing is most profitable for forage production. Hughes and Wilkins (11) at the Iowa Station found that the greatest yields of forage were obtained from a rate spacing the seeds ½ inch apart in 30-inch rows.

TABLE 6.—Acre Yields of Manchu and Peking Seed from Different Rates and Dates of Sowing

Dates sown	Manchu						Peking					
	Year				4-year average	4-year average of three rates	Year				4-year average	4-year average of three rates
	1923 Bu.	1925 Bu.	1926 Bu.	1927 Bu.	Bu.	Bu.	1923 Bu.	1925 Bu.	1926 Bu.	1927 Bu.	Bu.	Bu.
Thick rate												
April 10	......	33.1	38.4	32.3	34.6*	30.6	......	......	52.6	23.4	38.0†	33.5
April 15-20	43.5	30.4	38.9	32.2	36.2	32.6	28.3	35.0	41.8	23.3	32.1	31.3
May 1	39.4	31.8	34.4	27.1	33.1	30.4	21.4	35.5	31.5	22.6	27.7	28.3
May 15	37.4	30.9	36.4	28.5	33.3	30.2	21.6	42.6	41.6	22.9	32.1	28.9
June 1	34.8	34.0	38.6	15.8	30.8	29.5	16.7	35.2	39.8	11.2	25.7	24.9
June 15	32.4	30.5	31.4	20.1	28.6	27.0	16.6	28.6	36.9	12.6	23.6	21.6
July 1	23.0	24.2	39.1	......	28.7*	24.9	9.5	11.8	37.0	9.2	16.8	16.1
July 15	6.6	7.9	12.5	......	8.0*	6.8	......	2.3	12.9	......	7.6†	7.0
Aug. 1	......	......	6.0	......	......	......	......	......	7.2	......	......	......
Medium rate												
April 10	......	31.1	32.5	29.0	30.8*	......	......	......	45.4	22.1	33.7†	......
April 15-20	40.5	29.2	30.9	31.1	32.9	......	31.1	32.4	41.6	24.9	32.5	......
May 1	40.2	31.7	30.9	27.2	32.5	......	20.9	40.2	31.6	23.3	29.0	......
May 15	33.5	30.8	35.8	22.8	30.7	......	20.9	41.5	34.8	22.3	29.8	......
June 1	35.0	32.7	38.4	15.6	30.4	......	16.8	40.0	36.2	10.6	25.9	......
June 15	33.5	30.9	33.1	16.2	28.4	......	17.1	24.2	30.9	13.3	21.3	......
July 1	23.2	18.9	32.0	......	24.7*	......	11.6	10.6	34.5	7.7	16.1	......
July 15	5.9	6.2	12.3	......	8.1*	......	......	2.0	12.9	......	7.4†	......
Aug. 1	......	......	5.0	......	......	......	......	......	2.9	......	......	......
Thin rate												
April 10	......	20.6	26.6	32.1	26.4*	......	......	......	33.7	23.7	28.7†	......
April 15-20	37.3	23.2	27.7	26.8	28.7	......	26.8	30.9	37.6	22.2	29.3	......
May 1	32.8	23.7	23.8	21.7	25.5	......	19.5	41.2	30.5	22.3	28.3	......
May 15	34.1	25.6	26.3	20.8	26.7	......	18.8	33.9	26.9	19.6	24.8	......
June 1	34.5	25.6	33.5	15.8	27.3	......	16.4	32.6	33.2	10.8	23.2	......
June 15	29.9	22.9	31.3	12.1	24.0	......	16.2	18.0	31.4	14.1	19.9	......
July 1	19.5	16.7	27.6	......	21.2*	......	10.7	9.3	33.1	8.6	15.4	......
July 15	3.7	4.3	4.6	......	4.2*	......	......	2.0	9.8	......	5.9†	......
Aug. 1	......	......	3.0	......	......	......	......	......	1.4	......	......	......

*3-year average.
†2-year average.

It also appears from the above results that a lower rate of seeding than the thick rate might produce maximum yields of seed, since the medium rate yielded very nearly as much as the thick rate. Hughes and Wilkins found that a one-inch spacing of seed in 30-inch rows produced a greater yield of seed than a ½-inch spacing or than a 2-inch or wider spacing. In comparing the results of the two experiments, it should be borne in mind that in the present experiment with rows spaced 28 inches apart there would be a greater number of plants per acre, at the same spacing in the row, than in the experiment of Hughes and Wilkins, with rows 30 inches apart and that soil fertility and moisture profoundly affect rate of sowing.

TABLE 7.—Acre Net Seed Yields of Manchu and Peking Soybeans* from Different Rates and Dates of Sowing

4-year average except where noted

Dates sown	Manchu				Peking			
	Rates sown			Average of three rates	Rates sown			Average of three rates
	Thick	Medium	Thin		Thick	Medium	Thin	
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
April 10	32.6§	30.4§	26.2§	29.7	37.0‡	33.5‡	28.6‡	33.0‡
April 15–20	34.2	32.5	28.5	31.7	31.1	32.3	29.2	30.8
May 1........	31.1	32.1	25.3	29.5	26.7	28.8	28.2	27.9
May 15........	31.3	30.3	26.5	29.3	31.1	29.6	24.7	28.3
June 1........	28.8	30.0	27.1	28.6	24.7	25.7	23.1	24.5
June 15........	26.6	28.0	23.8	26.1	22.6	21.1	19.8	21.1
July 1........	26.7§	24.3§	21.0§	24.0	15.8§	15.9§	15.3§	15.6
July 15........	6.0§	7.7§	4.0§	5.9	6.6§	7.2§	5.8§	6.5
Aug. 1........	4.0†	4.6†	2.8†	3.4	6.2†	2.7†	1.3†	3.4
Av. of all dates	24.6	24.4	20.5	....	22.4	21.8	19.5	....

*Seed deducted.
†One year only.
‡2-year average.
§3-year average.

Although a fair amount of work has been done on rate of sowing soybeans, few experiments have compared yields of hay and seed from various rates and none except that reported by Hughes and Wilkins have dealt with the spacing of plants in the rows.

Wiancko and Mulvey (27) at the Indiana Station, using the Ito San and Early Brown varieties, compared sowing rates of 60 and 90 pounds of seed per acre, drilled solid. Although the two rates produced almost identically the same yields of seed, the 90-pound rate produced over 700 pounds more hay per acre.

The effect of date of planting on the yield of forage.—It is evident that the plantings of both varieties made on May 1 and May 15 have produced the highest yields of forage when the 5-year average is considered. (See Table 4, average of three rates). Both varieties planted on dates ranging from April 15 to 20 have produced about the same yields as when planted on June first, and when planted April 10 have produced more than when planted June 15.

Beyond these similarities, the two varieties show some differences in performance. Manchu planted on the four dates ranging from April 15-20 to June 1 produced yields very much alike, considering all three rates of planting, with differences probably within the error of the experiment. Peking, however, produced significantly higher yields from the May 1 and 15 dates at all rates.

The yields of both varieties show similar decided decreases when plantings are made successively after June 15.

It should be noted that yields from the April 10 planting date are 2- and 3-year averages and are not strictly comparable to the other yields. From observations of early plantings over a period of years, the writer is confident that these yields are about what should be expected. The low yields of early planted Manchu were partially caused by freezing back of the plants in May, 1924. Peking was more seriously injured than Manchu by this frost; thus, forage harvests were not made. In 1923, Peking was inadvertently cut too early for proper forage yields, so that neither the 1923 nor the 1924 forage yields of Peking were included in the average.

Aside from frost, the causes of low yields of the early plantings are not entirely clear. There was a slight reduction in stand caused by slow germination. In addition, it appears that the plantings did not make as efficient use of the growing season. The plants matured before the end of good growing weather. There is also a possibility that the conditions under which the early plantings germinated may have affected the subsequent development of the plants. Kidd and West (13) report that the temperature at which seeds germinate materially affects the subsequent life of the seedling. Data on this particular phase of "physiological predetermination" in soybeans, however, are lacking at present.

The effect of date of planting on the yield of seed.—Evidently, seed yields of the two varieties are not closely correlated with forage yields. When the average of the three rates is considered, it is evident that the earlier sowing dates are more conducive to the production of higher yields of seed than of forage. (See Table 6). It is also noticeable that Manchu produced the best yields when sown at dates ranging from April 10 to June 1 and continued to make fair yields when sown as late as July 1. Especially is this true when sown at the thick rate. Peking, however, decreased rapidly in yielding ability when sown on successive dates later than May 15. The lack of consistency in the May 1 yields of Peking can largely be explained by dry weather in 1925 and 1926, which, because of its time of occurrence and duration, affected this planting in particular. This was to be expected, as Peking is the later variety. In only 2 years has Peking matured sufficiently to produce seed when planted on July 15, and in only one year when planted August 1. Manchu, on the other hand, has produced seed every year from these plantings; the plants, however, rarely mature.

Although the best date of planting is largely a local problem, the work of other stations is of interest. Hughes and Wilkins (11) at the Iowa Station, using a similar range of dates to those employed in the present study (weekly intervals from April 19 to July 5), obtained similar results.

In this experiment there was little difference in the seed yields of the plantings from May 3 to 24, and little difference in the hay yields of the plantings from April 19 to May 24. Plantings made after May 24 produced successively lower yields. As in the present study, there was a decrease in the seed yields from the April plantings but no decrease in the hay yields.

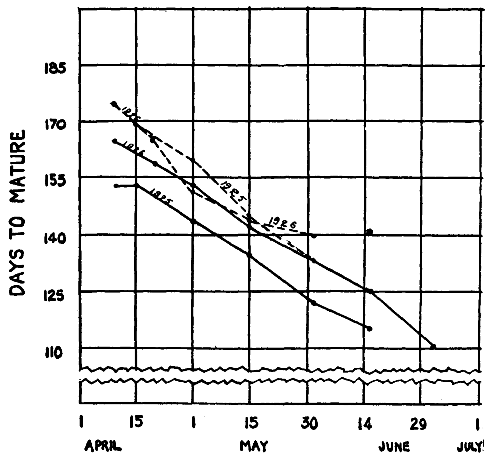

Fig. 2.—The effect of planting at different dates on the length of growth period of soybeans

——— Manchu - - - - Peking

Thatcher (21) at the Ohio Station reports the yields of plantings made May 7, 8, 19, and 31, and June 12. Practically equally high yields were obtained from plantings on the first two dates, which were more favorable than the later ones.

The effect of the date of planting on growth periods.—The variations in the number of days from planting to blooming, from blooming to maturity, and in the total number of days in the life period for the plantings made at different dates are given in Table 8. Mooers (18) has given somewhat similar data for three varieties grown in Tennessee.

In 1925, a difference of 61 days in planting date of Manchu resulted in a difference of 38 days in the life period. For Peking in the same year, a difference of 61 days in date of planting resulted in a difference of 46 days in the life period. In 1926, comparable figures for Manchu were 81 and 55, and for Peking 51 and 35. This is shown graphically in Figure 2.

The graph would seem to indicate that the regression or delay in date of ripening for a given delay in date of planting followed a straight line throughout the range. Accordingly, regression coefficients from the equations for straight lines were fitted to the data with date of planting as the independent variable and date of ripening as the dependent variable. The method of least squares was used. These coefficients indicate the delay in ripening (given in days) for each day's delay in planting and represent a different function of the data than that shown in Figure 2.

TABLE 8.—Effect of Date of Sowing on the Growth Period of Soybeans

Date sown	Days until emergence	Days until bloom	Date ripe	Days from bloom until ripe	Total days to mature
		Manchu—1925			
April 10	....	66	Sept. 10	87	153
April 15	....	72	Sept. 15	81	153
May 1	....	61	Sept. 21	82	143
May 15	....	52	Sept. 28	83	135
June 1	....	45	Oct. 1	77	122
June 15	....	45	Oct. 8	70	115
July 1	....	35	....	....	....
		Peking—1925			
April 15	....	112	Oct. 1	57	169
May 1	....	102	Oct. 8	58	160
May 15	....	91	Oct. 8	54	145
June 1	....	78	Oct. 12	55	133
June 15	....	66	....	....	....
		Manchu—1926			
April 10	23	60	Sept. 22	105	165
April 20	16	46	Sept. 26	113	159
May 1	9	41	Oct. 1	112	153
May 15	10	52	Oct. 5	90	142
June 1	10	41	Oct. 11	92	133
June 15	7	43	Oct. 18	82	125
July 1	8	43	Oct. 18	67	110
July 15	11	40	Oct. 18*	....	....
Aug. 1	5	....	Oct. 18*	....	....
		Peking—1926			
April 10	23	109	Oct. 2	66	175
April 20	16	110	Oct. 2	55	165
May 1	9	103	Oct. 4	48	151
May 15	10	93	Oct. 7	51	144
June 1	10	81	Oct. 18	59	140
June 15	7	67	Oct. 18	....	....
July 1	8	55	Oct. 18, ⅓ ripe*	....	....
July 15	11	48	Oct. 18*	....	....
Aug. 1	5	....	Oct. 18*	....	....

*Killed by frost.

In 1925 for each day's delay in planting, Manchu was delayed .395 days in ripening, and Peking .215. In 1926, Manchu was delayed .343 days for each day in delay of planting, and Peking .300 days. In spite of the fact that the graph indicates the relation between date of planting and ripening to be constant throughout the season, the writer believes this point is open to question. Observation leads to the belief that the delay in ripening for each day's delay in planting becomes progressively less as the season progresses up to a certain time. Late summer rains or cool weather in the fall doubtless delay the ripening of the late sowings. It should be noted also that the data are subject to some error because of the difficulty of recording exact ripening dates, as well as from the small amount of data available.

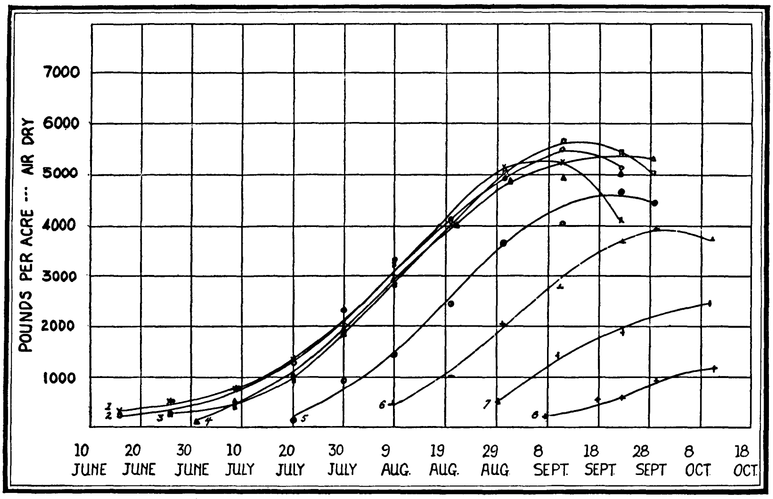

Fig. 3.—Manchu soybeans sown at different dates, acre yields of tops. 3-year average of 3 planting rates

Planting dates

1. April 20	4. June 1	7. July 15
2. May 1	5. June 15	8. August 1
3. May 15	6. July 1	

The possible relation of temperature and moisture to date of planting.—Figure 3 presents another picture of the growth of the soybeans planted on the different dates. The most noticeable point is the close coincidence of the curves of the first four plantings of Manchu during the period of rapid growth. The Peking data show a similar tendency. Evidently, the vegetative growth of the early plantings is held back for a time. That there is not a commensurate delay in the physiological development of the plants, however, is shown by the ripening dates of the various sowings (Table 8).

It will be noted that, not only does the grand period of vegetative growth occur later in the life of the early plantings, but there is a lag in the growth of the early plantings lasting until after July 15. An average of the mean, daily air temperature for the 3 years shows that a summer temperature of 70° F. is reached about July 5, or about 2 weeks before the early plantings reach their maximum rate of growth.

The early growth of the first two or three plantings was, no doubt, delayed by external factors; temperature being probably the most important of these. The cause of the later lag is not clear, however. Stunting, "physiological predetermination" as discussed by Kidd and West (13), or soil temperature in relation to nodule development may be only suggested as causes. Jones and Tisdale (12) found a considerable increase in the development of nodules on inoculated soybeans at approximately 75° F.

Referring again to Figure 3, it is to be noted that the curves for the June 15 and July 1 plantings parallel the curves of the previous plantings. The rate of growth of these plantings during their "grand period" of growth is as rapid, or very nearly so, as that of the preceding ones. The total growth, however, is not as great as that of the first plantings. The reproductive phase of growth apparently curtails the vegetative phase. Garner and Allard (8, 9) found that the shortening of the light period was a very important factor in bringing the soybean plant to maturity.

It is also evident (Fig. 3 and Table 9) that the plantings made July 15 and August 1 grew much more slowly than any of the preceding plantings. Among the factors causing this, moisture supply was, no doubt, important. Soil moisture is often deficient at Columbus during the latter part of July and during August; this was especially true in 1924 and 1925. The yields of 1926 (a year of plentiful rainfall in August), given in Table 9, indicate what the late sowings produced when sufficient moisture was available.

Evidently, the soybean is drouth resistant only when the roots have made a good growth before drouth comes.

LIFE HISTORY OF THE SOYBEAN

Development of the various plant parts. *Stems and leaves.*—As previously indicated, the growth of stems and leaves was comparatively slow in the early life of the plant and, regardless of date of planting, was more rapid after early July. Growth of these parts continued until about the time seed formation began. During the period of growth of stems and leaves, the weight of leaves

TABLE 9.—Yield of Air-dry Forage per Acre Harvested at Intervals

Date sown	Date harvested	Manchu			Peking		
		Rates sown			Rates sown		
		Thick	Medium	Thin	Thick	Medium	Thin
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1924 April 19	Aug. 10	4195	3364	3349	...	...	...
	Aug. 31	4270	4630	4542	...	...	...
May 1	June 26	954	386	219	514	262	180
	July 7	2343	1175	975	1330	1098	669
	July 18	4293	2315	1986	2526	1865	1690
	Aug. 1	4797	3609	3567	3524	3230	2564
	Aug. 10	5231	3963	4285	3794	3416	3531
	Aug. 28	5921	5363	5468	...	...	...
	Sept. 13	...	...	...	5003	4509	4570
May 15	July 17	3089	1852	1469	2150	1325	1176
	Aug. 1	4290	3432	2848	4198	3030	2245
	Aug. 10	5377	4120	3971	3992	3300	2942
	Aug. 28	6198	5921	5298	5514	4514	4514
	Sept. 13	4704	4501	4941	5507	4977	4465
	Sept. 23	...	...	...	5262	5988	5316
June 1	July 17	2011	1260	766	1551	995	725
	Aug. 1	3704	2963	2477	3256	2305	1507
	Aug. 10	4012	3614	3315	3117	2821	2058
	Aug. 28	5921	5671	5144	5064	4259	4221
	Sept. 13	5028	5113	3652	4897	4570	4648
	Sept. 23	4699	4627	3909	6139	6006	6155
June 15	Aug. 1	1445	1047	913	1587	733	676
	Aug. 10	1880	1559	1201	1821	1109	985
	Aug. 28	4125	4020	3230	3524	3086	2536
	Sept. 13	3957	3822	4622	3879	3600	3642
	Sept. 23	4784	4496	4626	5435	5129	4699
	Oct. 10	...	...	...	2868	4655	4933
July 15	Aug. 28	1152	784	648	862	599	432
	Sept. 13	...	1517	1073	1466	944	1073
	Sept. 21	2279	1800	1394	1890	1569	1404
	Oct. 10	2780	2315	1339	2914	2302	2683
Aug. 1	Sept. 13	810	257	147	360	249	162
	Sept. 23	805	412	224	604	386	260
	Oct. 10	1376	970	545	1232	823	571
1925 April 15	June 26	731	405	322	480	415	196
	July 1	1077	741	549	672	559	292
	July 11	1911	1437	1214	1327	1334	1101
	July 22	1989	2267	1667	1979	1931	1766
	Aug. 1	3701	3694	2953	2878	2895	2483
	Aug. 10	4037	4792	3722	3746	3862	3529
	Aug. 20	5437	6026	4322	4606	4709	4558
	Aug. 31	4668	6685	2785	5615	5855	6013
	Sept. 10	2360	3914	2000*	5210	5371	5824
May 1	June 16	271	206	237	446	...	...
	June 26	521	350	394	686	250	134
	July 1	871	724	1283	981	580	343
	July 11	1780	1646	1908	936	1259	789
	July 22	2641	2511	2980	2771	1957	1664
	Aug. 1	3567	3238	3564	3049	2916	2319
	Aug. 10	4480	4685	4082	4329	3958	2826
	Aug. 20	5474	5127	4953	5773	4987	3636
	Aug. 31	6668	5944	4716	6791	6171	5920
	Sept. 10	6000*	5152	4500*	6315	5145	5000*

*Estimated.

TABLE 9.—Yield of Air-dry Forage per Acre Harvested at Intervals.—Cont.

Date sown	Date harvested	Manchu			Peking		
		Rates sown			Rates sown		
		Thick	Medium	Thin	Thick	Medium	Thin
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1925 May 15	June 26	545	292	144	515	168	117
	July 1	796	425	326	549	292	158
	July 11	1568	1135	947	1540	933	576
	July 22	2686	2000	2027	2435	1530	1698
	Aug. 1	3776	3138	2638	3036	2630	2487
	Aug. 10	5656	4257	3622	3637	3440	3111
	Aug. 20	5797	5965	4689	4936	4315	4394
	Aug. 31	7001	6174	4984	6006	5317	4504
	Sept. 10	7148	6668	4421	5491	5965	5179
	Sept. 21	5711	4730	4332	5574	6291	5769
June 1	July 1	418	38	41	192	51	48
	July 11	1005	271	274	792	192	240
	July 22	1825	902	645	1341	830	737
	Aug. 1	2669	1396	1242	1712	1430	1300
	Aug. 10	3505	2236	2278	2353	2154	2020
	Aug. 20	4500	3484	3403	3948	3478	3186
	Aug. 31	5526	4171	4436	4648	4020	3855
	Sept. 10	5622	4946	4260	5354	5107	4356
	Sept. 21	5509	4939	5509	6045	6586	5464
	Sept. 28	5485	4486	5515	6804	7388	6000*
June 15	July 22	377	154	154	720	120	86
	Aug. 1	1629	765	453	1135	525	285
	Aug. 10	2418	1080	892	1777	827	556
	Aug. 20	3382	2278	1640	2710	1526	1681
	Aug. 31	5248	3180	2394	3797	2792	2219
	Sept. 10	5622	3687	2751	4294	3094	2715
	Sept. 21	6524	4191	3272	5615	4768	3427
	Sept. 28	7213	4099	3293	6678	5025	4301
	Oct. 10	5035	....	....	6171	4730	4644
July 1	Aug. 10	734	257	209	731	240	172
	Aug. 20	2010	724	216	1379	648	439
	Aug. 31	3142	1537	1180	2230	1214	919
	Sept. 10	3872	2068	2233	2809	1832	1403
	Sept. 21	5032	3296	2912	4054	2799	2343
	Sept. 28	5128	3557	3392	4706	3773	3060
	Oct. 10	5114	3773	2867	5094	3989	3509
July 15	Aug. 31	1135	377	244	638	302	182
	Sept. 10	1348	792	415	785	583	391
	Sept. 21	2415	1484	1077	1667	1406	943
	Sept. 28	2964	2003	1293	2634	1796	1307
	Oct. 10	2806	2257	1681	3193	2559	1993
Aug. 1	Sept. 10	480	147	154	370	72	99
	Sept. 21	936	326	278	806	254	161
	Sept. 28	1276	520	412	1173	449	319
	Oct. 10	1286	597	480	1279	631	521
1926 April 10	June 16	429	219	135	462	219	126
	June 28	838	611	388	1062	557	349
	July 1	1521	1166	991	1574	1007	748
	July 9	2386	2097	1811	2489	2067	1530
	Aug. 1	3241	3021	2454	3160	2765	2279
	Aug. 10	3872	3842	3387	4290	3739	3194
	Sept. 10	6184	5757	4557	7098	7348	7277
	Sept. 22	....	....	....	7015	6646	5415

*Estimated.

TABLE 9.—Yield of Air-dry Forage per Acre Harvested at Intervals.—Concl.

Dates sown	Date harvested	Manchu			Peking		
		Rates sown			Rates sown		
		Thick	Medium	Thin	Thick	Medium	Thin
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1926 April 20	June 16	547	265	148	430	219	167
	June 28	920	707	436	835	558	439
	July 9	1585	1244	927	1309	982	853
	July 20	2743	2343	1421	2163	1738	1679
	July 30	3542	3163	2467	2779	2168	2567
	Aug. 10	4815	4202	2701	3855	3525	3589
	Aug. 20	5665	4973	4606	4462	4086	4165
	Aug. 30	6507	5743	5375	5630	5570	5419
	Sept. 11	5666	5430	4584	6773	6010	5984
	Sept. 22	....	....	....	6880	6797	6525
	Oct. 1	....	....	....	6920	6720	6615
May 1	June 28	736	559	414	757	401	323
	July 9	1162	1083	821	1302	717	657
	July 20	2181	1863	1542	1880	1736	1257
	July 30	3181	2477	2330	2532	2482	1944
	Aug. 10	4118	3476	3379	3012	3344	2738
	Aug. 20	5112	4332	4154	3870	4104	4640
	Aug. 31	5903	4920	4679	4960	5273	4408
	Sept. 10	5883	5395	4907	6282	5737	4725
	Sept. 22	....	....	....	6586	6141	5721
	Oct. 1	....	....	....	6376	6907	5920
May 15	July 9	562	485	344	676	411	553
	July 20	1505	1181	913	1366	1079	691
	July 30	2259	1588	1274	1852	1522	1198
	Aug. 10	3597	3154	2476	2825	2560	1967
	Aug. 20	4671	4354	3415	3594	3078	2808
	Aug. 31	5981	5148	4450	4900	4687	3604
	Sept. 10	5759	5463	5098	5706	5762	4658
	Sept. 22	5961	5395	4224	6748	5817	5800
	Oct. 1	5891	5067	4503	6513	6360	5853
June 1	July 20	1074	529	242	895	712	350
	Aug. 1	1509	1099	716	1634	1101	807
	Aug. 10	2962	2167	2115	2419	1741	1442
	Aug. 20	4130	3363	2360	3054	2514	2378
	Aug. 31	5107	4449	3521	4881	4140	3644
	Sept. 10	5619	4715	4562	5480	4829	4307
	Sept. 22	6101	4888	4820	7154	5681	5535
	Oct. 1	6368	5743	4258	6713	5883	5655
June 15	Aug. 10	1676	1423	678	1452	845	699
	Aug. 20	2537	2214	1349	2284	1688	1281
	Aug. 31	4780	3397	2343	3407	2578	2300
	Sept. 10	5025	3777	2800	4288	3906	3156
	Sept. 22	5672	4530	4082	6096	5251	4703
	Oct. 1	5643	4160	3803	6059	4558	5329
July 1	Aug. 10	502	407	436	878	449	477
	Aug. 20	1421	961	723	1686	1056	864
	Aug. 31	2504	2055	1748	2332	1855	1449
	Sept. 10	3292	2822	2500	3720	2794	2565
July 15	Aug. 31	803	647	563	1186	849	663
	Sept. 10	1666	1536	1350	1736	1566	1133
	Sept. 22	2189	2135	1909	3093	2917	2072
	Oct. 1	2665	2005	1184	3739	3153	2554
	Oct. 10	2998	2715	2062	5836	3728	3786
Aug. 1	Sept. 10	462	479	240	462	479	240
	Sept. 22	1056	692	588	1056	692	588
	Oct. 1	1537	988	815	1537	988	816
	Oct. 10	2416	1664	1109	2413	1664	1109

*Estimated.

of both varieties increased faster than that of the stems. (See Table 10 and Figs. 4 and 5). The leaf-stem ratio, however, becomes progressively less as both stems and leaves gain in total weight, Table 2. At about 40 days after planting or 30 days after emergence, the leaves may comprise 70 to 80 per cent of the combined weight of leaves and stems. After this, the percentage of leaves drops to approximately 60 just prior to leaf fall.

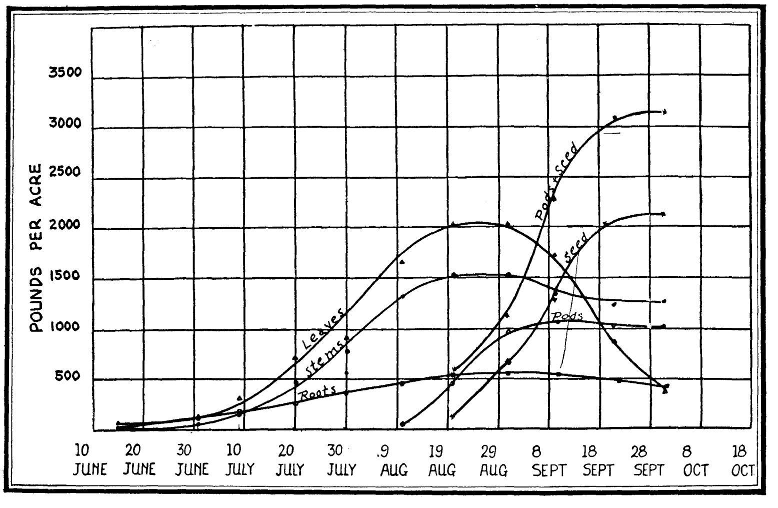

Fig. 4.—Development of Manchu Soybeans as shown by acre yields of plant parts. Planted May 15, 1926

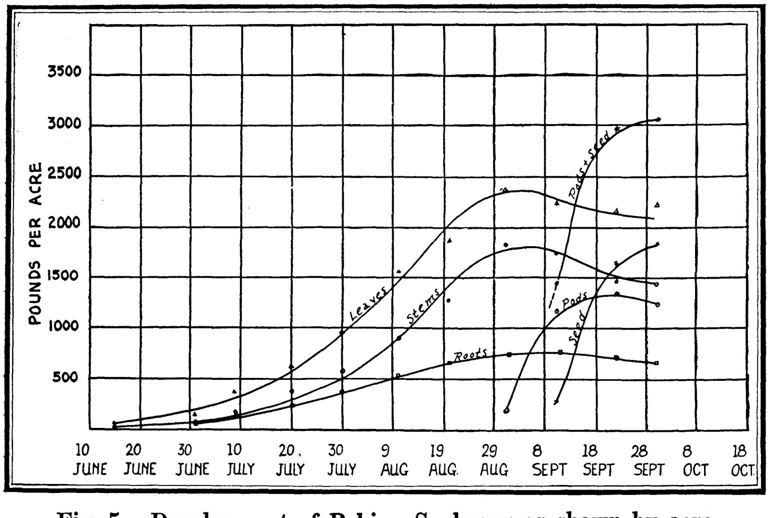

Fig. 5.—Development of Peking Soybeans as shown by acre yields of plant parts. Planted May 15, 1926

TABLE 10.—Development of Manchu and Peking Soybeans, As Shown by Acre Yields of Different Plant Parts‡

Manchu

Date harvested	Days after planting	Stems Lb.	Leaves Lb.	Roots Lb.	Pods Lb.	Pods and seeds Lb.	Seeds Lb.	Total tops Lb.
Sown May 15, 1925								
June 26	42	91	236	...	...	...	...	327
July 1	47	129	387	...	...	...	...	516
July 11	57	422	795	...	...	...	...	1217
July 22	68	897	1341	...	...	...	...	2238
Aug. 1	77	1239	1945	...	...	...	...	3184
Aug. 10	87	1773	2310	...	429	...	...	4512
Aug. 20	97	1590	2780	...	921	1114	192	5484
Aug. 31	108	1858	2294	...	908	1895	993	6053
Sept. 10	118	1611	1252	...	1027	3216	2189	6079
Sept. 21	129	1172	620	...	1098	3127	2029	4924
Sown June 15, 1925								
July 9	24	25*	75*	58	...	...	...	100
July 22	37	74	154	...	...	...	...	228
Aug. 1	47	279	670	241	...	...	...	949
Aug. 10	56	528	935	219	...	...	...	1463
Aug. 20	66	791	1642	323	...	...	...	2433
Aug. 31	77	900*	1861	384	...	628	...	3607
Sept. 10	87	892	1580	379	...	1548	...	4020
Sept. 21	98	881	1357	333	...	2424	...	4662
Sept. 28	105	803	862	...	...	3203	...	4868
Sown May 15, 1926								
June 15	31	30*	70*	26	...	...	...	100
July 1	47	65*	135*	137	...	...	...	200
July 9	56	146	318	160	...	...	...	464
July 20	67	490	710	250	...	...	...	1200
July 30	77	797	910	375	...	...	...	1707
Aug. 10	88	1338	1664	480	74	...	...	3076
Aug. 20	98	1530	2020	545	489	597	108	4147
Aug. 31	109	1527	2025	570	961	1641	680	5193
Sept. 10	119	1349	1708	530	1093	2383	1290	5440
Sept. 22	131	1226	898	480	1044	3069	2025	5193
Oct. 1	140	1278	485	437	1000*	3144	2144	4907

Peking

Date harvested	Days after planting	Stems Lb.	Leaves Lb.	Roots Lb.	Pods Lb.	Pods and seeds Lb.	Seeds Lb.	Total tops Lb.
Sown May 15, 1925								
June 26	42	58	209	...	...	...	...	267
July 1	47	87	246	...	...	...	...	333
July 11	57	284	732	...	...	...	...	1016
July 22	68	570	1318	...	...	...	...	1888
Aug. 1	77	862	1856	...	...	...	...	2718
Aug. 10	87	1270	2126	...	...	...	...	3396
Aug. 20	97	1601	2947	...	...	...	...	4548
Aug. 31	108	2142	3134	...	...	...	...	5276
Sept. 10	118	1952	2856	...	593	737	144	5545
Sept. 21	129	1611	2674	...	747	1593	846	5878
Oct. 10	...	1500*	2200*	...	800*	2980	1980	6480
Sown June 15, 1925								
July 9	24	20*	55*	40	...	...	...	75
July 22	37	84	225	...	...	...	...	309
Aug. 1	46	143	505	128	...	...	...	648
Aug. 10	56	326	727	164	...	...	...	1053
Aug. 20	66	590	1382	266	...	...	...	1972
Aug. 31	77	1072	1864	386	...	...	...	2936
Sept. 10	87	1196	2172	500	...	...	...	3368
Sept. 21	98	1183	2154	575	...	1266	...	4603
Sept. 28	105	1056	2385	575	...	1894	...	5335
Oct. 10	118	1073	1663	525	...	2446	...	5182
Sown May 15, 1926†								
June 15	31	20*	55*	28	...	...	...	75
July 1	47	65*	135*	96	...	...	...	200
July 9	55	159	388	140	...	...	...	547
July 20	66	384	662	225	...	...	...	1045
July 30	76	570	954	378	...	...	...	1524
Aug. 10	87	897	1554	522	...	...	...	2451
Aug. 20	97	1280	1880	650	...	...	...	3160
Aug. 31	108	1812	2392	710	193	...	...	4397
Sept. 10	118	1736	2215	758	1161	1424	263	5375
Sept. 22	130	1463	1684	700	1335	2975	1640	6122
Oct. 1	139	1423	1733	655	1236	3086	1850	6242

*Estimated. †Medium and thin rates averaged. ‡Average of three rates of sowing.

The maximum weight per acre of both leaves and stems of Manchu, sown May 15 (leaves, 2400 pounds; stems, 1691 pounds, 2-year average of three rates) was recorded on August 20. The maximum yield of Peking leaves and stems was recorded 11 days later, August 31 (2267 pounds per acre of leaves, 1877 pounds per acre of stems, 2-year average of two rates). At the time of maximum leaf yields, the seeds of both varieties were less than one-third grown. There occurred a noticeable decrease in the weight of stems at the end of the season, varying roughly from 250 to 600 pounds per acre. It occurred consistently in all rates of planting with both varieties and in both years. Willard's (28) data show the same decrease in the weight of stems, as do also Thatcher's data in Part II of this bulletin.

Pods.—Pod formation began 10 to 15 days before the leaves and stems had reached their maximum growth. The pods increased in weight to about 1100 pounds per acre in Manchu and 1300 pounds per acre in Peking. Observation and preliminary studies lead to the belief that this yield of Peking pods is higher than normal and that Peking ordinarily does not produce a greater yield of pods than Manchu. At the end of the season, there was a decrease in the weight of the pods of both varieties. This decrease was also reflected in the content of chemical constituents discussed later.

Seed.—Seed formation began early in August, about the time the stems and leaves reached their maxima. In Figures 4 and 5 it is observed that the increase in weight of seed per acre presents by far the steepest curve. In fact, the increase in weight of the seed may reach a rate of over 50 pounds per acre per day.

Apparently, in the plants studied there was little increase in yield of roots after August 20; whereas, nearly all the growth of pods and seeds takes place after this date. Although the residual fertility value of the roots is almost too small to consider practically, it is interesting to note that there is comparatively little, if any, gain in roots after the hay stage of the plant has been reached. The total root yield of Peking reached a maximum of 575 pounds per acre in 1925 and 758 in 1926, as compared with 379 and 591, respectively, of Manchu for the 2 years. (See Tables 11 and 12).

Influence of soil type on root growth.—Soil conditions apparently play an important part in the depth and distribution of the roots of soybeans. This was observed in 1925 and studied further in 1926. Figure 6 shows mature Manchu plants grown on Miami silty clay loam and Clyde silty clay loam. The average depth of the root systems of both varieties studied was found to be about 26 inches on the Miami soil. On soils of similar texture, of both the Brookston and Clyde series, roots extended to a depth of over 5

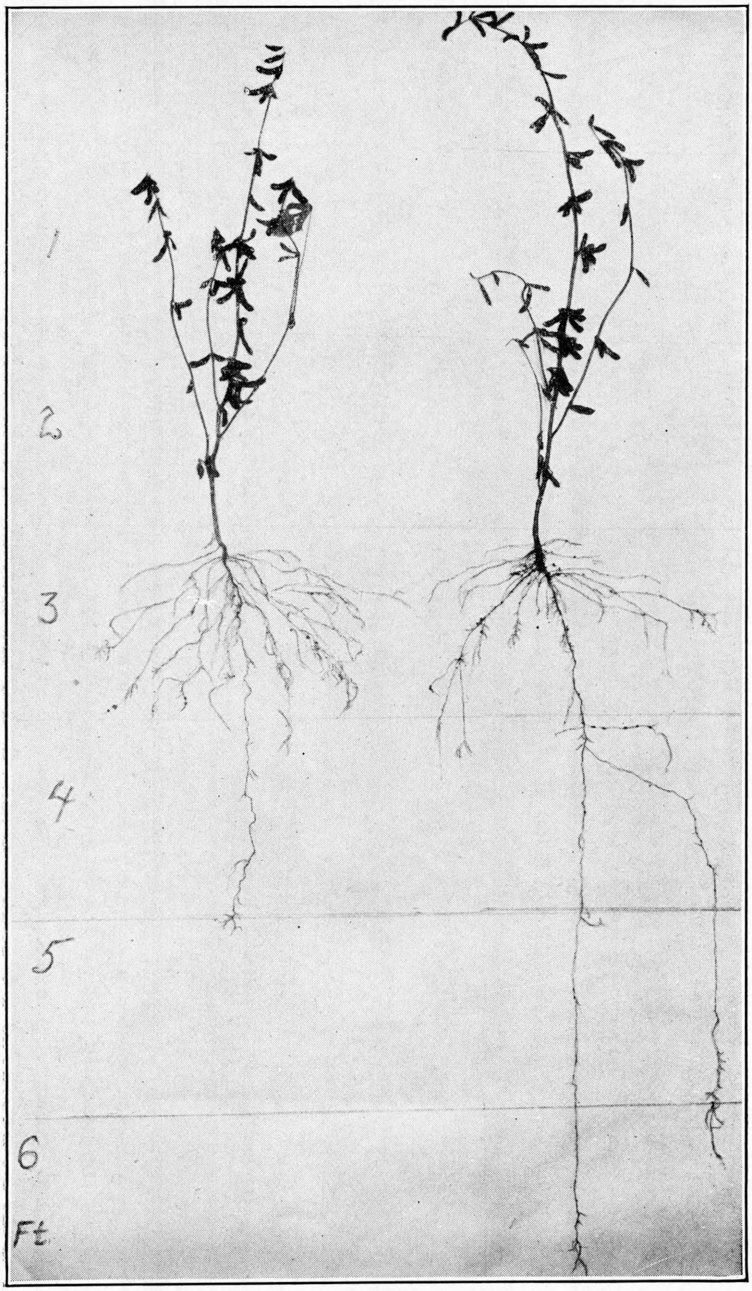

Fig. 6.—Manchu Soybeans grown on Miami silty clay loam (shallow roots) and on Clyde silty clay loam (deep roots)

TABLE 11.—Soybean Root Yields and Root-top Ratios

Dry weights per acre

Dates of harvest	Approx. days after emergence	Manchu: Stage of maturity	Manchu: Tops	Manchu: Roots	Manchu: Per cent plant in roots	Manchu: Root-top ratio	Peking: Stage of maturity	Peking: Tops	Peking: Roots	Peking: Per cent plant in roots	Peking: Root-top ratio
Sown June 15, 1925‡											
July 8	17	...	100†	58	36.7	1: 1.7	...	75	40	34.2	1: 1.8
Aug. 1-3	40	...	949	241	20.2	1: 2.9	...	648	128	16.4	1: 5.0
Aug. 10	49	Bloom started	1463	219	13.0	1: 6.6	...	1053	164	13.9	1: 6.4
Aug. 18-22	58	...	2433	323	11.6	1: 8.0	Blooming	1972	266	11.8	1: 7.4
Aug. 29	70	Pods formed	3607	384	9.2	1: 9.8	Pods forming	2936	389	10.7	1: 8.3
Sept. 14	85	Seeds forming	4400	379	7.2	1: 11.5	Pods formed	3860	575	12.9	1: 6.7
Sept. 23	94	Seeds formed	4662	333	7.2	1: 13.9	Seeds forming	4603	...	...	...
Oct. 14	115	Mature	...	...	...	...	Not fully ripe	5180	524	9.1	1: 9.0
Sown May 20, 1926§											
June 15	15	...	100†	26	21	1: 3.8	...	75	28	25	1: 2.8
July 1	30	...	200†	137	41	1: 1.5	...	200	96	33	1: 2.0
July 16	45	Bloom started	830	195	19	1: 4.3	...	790	171	18	1: 4.6
Aug. 1	61	Nearly full bloom	1700	406	19	1: 4.1	Buds	1520	413	21	1: 3.6
Aug. 15	76	Pods forming	3610	536	13	1: 6.7	Nearly full bloom	2800	627	18	1: 4.5
Sept. 8	100	Seeds forming	5440	591	10	1: 9.2	Pods formed	5370	758	12	1: 7.0
Oct. 10	132	Past maturity	5150	437	7	1: 13.0	Mature	6240	631	8	1: 10.9

*Theoretical date—Data from plants 17 days old.
†Estimated from growth curves.
‡Roots dug.
§Roots washed out.

feet, and the average depth for the plants studied was over 50 inches. In addition to being shallower, the roots of the plants grown on the Miami silty clay loam were more crooked and more branched than those grown on the Clyde or Brookston soils. It appeared that this difference was caused partly by the mechanical resistance to penetration of the soil. In the Miami soil, roots were observed to follow the cleavage surfaces between the soil granules. Weaver (26) reports differences in the roots of cereal crops grown on different soils of the western states.

TABLE 12.—Acre Yields of Total Tops for Various Dates of Sowing and Harvest

Date of harvest	Manchu					Peking				
	1924 Lb.	1925 Lb.	1926 Lb.	1927 Lb.	Av. Lb.	1924 Lb.	1925 Lb.	1926 Lb.	1927 Lb.	Av. Lb.
Sown May 1										
July 10–20.........	1497	1778	1862	1090	1557	1032	995	1624	762	1103
July 20–30.........	2864	2710	2663	1541	2444	2027	2131	2319	1206	1921
Aug. 1–10.........	3991	3456	3658	2863	3492	3106	2761	3031	2294	2798
Aug. 10–20.........	4993	4415	4553	3500	4365	3580	3704	4205	3085	3644
Aug. 20–30.........	5278	5184	5167	4040	4917	3950	4799	4880	3876	4376
Sept. 1–10.........	5584	5776	5395	4569	5331	4320	6294	5581	4668	5216
Sept. 10–20.........	5200	5152	5000*	4890	5051	4694	5780	6149	4911	5384
Sown May 15										
July 10–20.........	1200	1216	1200	800*	1104	800	1016	1045	699	890
July 20–30.........	2136	2237	1707	1357	1859	1550	1888	1524	1055	1504
Aug. 1–10.........	3523	3184	3076	2362	3036	3158	2718	2451	1958	2571
Aug. 10–20.........	4822	4511	4147	3180	4165	3411	3396	3160	2616	3146
Aug. 20–30.........	5400	5483	5163	3675	4930	4129	4548	4397	3360	4109
Sept. 1–10.........	5805	6053	5440	4005	5326	4847	5276	5375	4118	4904
Sept. 10–20.........	4715	6079	5193	3200*	4797	4983	5545	6122	4597	5312
Sown June 1										
July 20–30.........	1345	1124	1108	....	1192	1090	969	1181	....	1080
Aug. 1–10.........	3048	1769	2415	....	2411	2356	1481	1867	....	1901
Aug. 10–20.........	3647	2673	3284	....	3201	2665	2176	2649	....	2497
Aug. 20–30.........	4612	3795	4359	....	4255	3590	3537	4222	....	3783
Sept. 1–10.........	5578	4711	4965	....	5085	4515	4174	4872	....	4520
Sept. 10–20.........	4597	4942	5270	....	4936	4705	4939	6123	....	5256
Sept. 20–30.........	4411	5319	5456	....	5062	6100	6032	6048	....	6060
Sown June 15										
Aug. 1–10.........	1135	949	1259	....	1114	999	648	999	....	882
Aug. 10–20.........	1546	1463	2033	....	1681	1305	1053	1751	....	1370
Aug. 20–30.........	2660	2433	3507	....	2867	2177	1972	2762	....	2304
Sept. 1–10.........	3791	3607	3867	....	3755	3049	2936	3783	....	3256
Sept. 10–20.........	4133	4020	4761	....	4305	3575	3368	5350	....	4098
Sept. 20–30.........	4635	4662	4535	....	4611	5088	4633	5315	....	5012

*Estimated.

The root-top ratio.—Data on roots and root-top ratios are presented in Table 11. The 1925 data are from plants sown June 15, later than the best seeding date; the roots were dug rather than washed out. Because of the late sowing and the methods of obtaining the roots, the root yields were low.

In 1925, there was a gradual change in the root-top ratio from about 1 : 2, when the plants were 17 days old, to about 1 : 13, at maturity.

In 1926, there appeared to be five rather distinct stages of relative root and top development in both varieties. During the first period, the top growth went on rapidly until about 15 days after emergence; at this time the Manchu root-top ratio was 1 : 3.8 and Peking 1 : 2.8. The second period of 15 days was characterized by a comparatively more rapid root growth than top growth. During this time, the root-top ratios of Manchu and Peking decreased to 1 : 1.5 and 1 : 2, respectively. During the period lasting until bloom started, top growth went on more rapidly than root growth until a root-top ratio of about 1 : 4 or 1 : 4.5 was reached. These root-top ratios held until blooming time. In the period following blooming, the top growth was relatively greater than the root growth and the ratios widened progressively until maturity. Uhland (22) reports root percentages which indicate fluctuations in relative root and top growth, although different from those reported here.

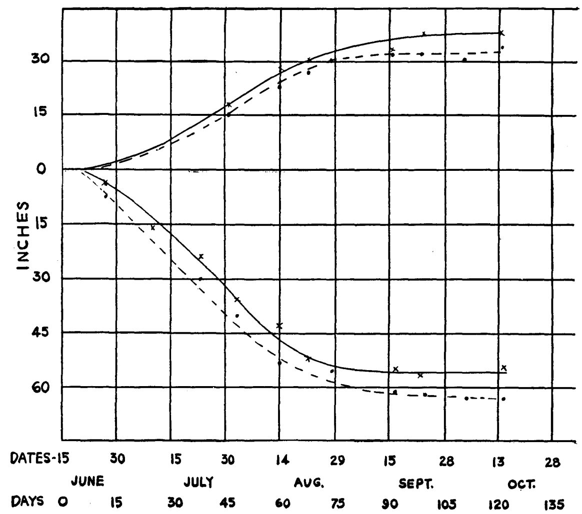

Fig. 7.—The development of soybeans as shown by height of tops and depth of roots. Sown June 15, 1925.
——— Manchu - - - - Peking

The final root-top ratios of 1 : 13 and 1 : 11 in Manchu and Peking, respectively, are probably somewhat wide, since they are from plants past maturity. There was doubtless some loss of roots in harvesting at this time. Thatcher (21) reports a root-top ratio of 1 : 16 for soybeans at maturity. In Part II of this bulletin, his findings agree well with those herein presented, considering the geographical, varietal, and soil differences.

Taking height of top and depth of root as criteria, a picture of the relative development of roots and tops is given in Figure 7. Figures 8 to 12 also show the growth of roots and tops at various stages. Peking apparently made the more rapid root growth of the two varieties; whereas Manchu made the more rapid top growth. The latter fact is borne out by other observations.

The following figures, 8 to 12 inclusive, show soybean plants grown in soil "cans" in 1926 and harvested at 15-day intervals. Planted May 20.

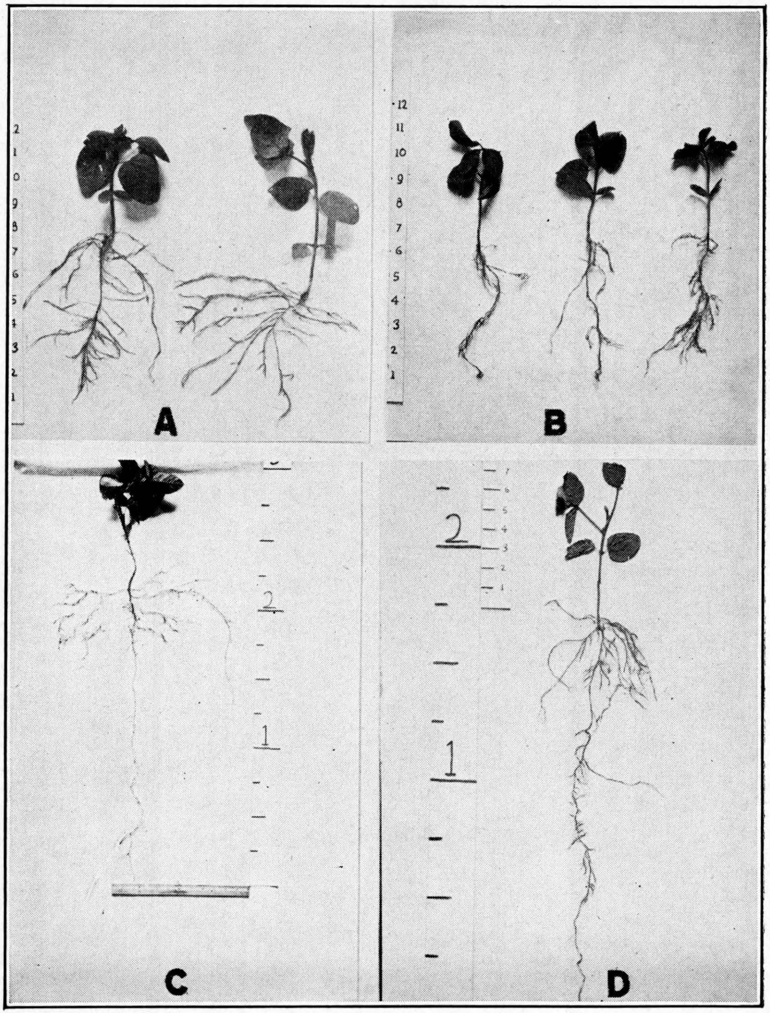

Fig. 8.—Upper, Manchu (A) and Peking (B) soybeans, June 16, 27 days after planting. Lower, Manchu (C) and Peking (D) soybeans, July 1, 41 days after planting

Total tops.—The maximum yield of total tops of Manchu planted May 15 was recorded on September 10 in both 1925 and 1926 (6079 pounds per acre, average of three rates in 1925; 5440 pounds in 1926).

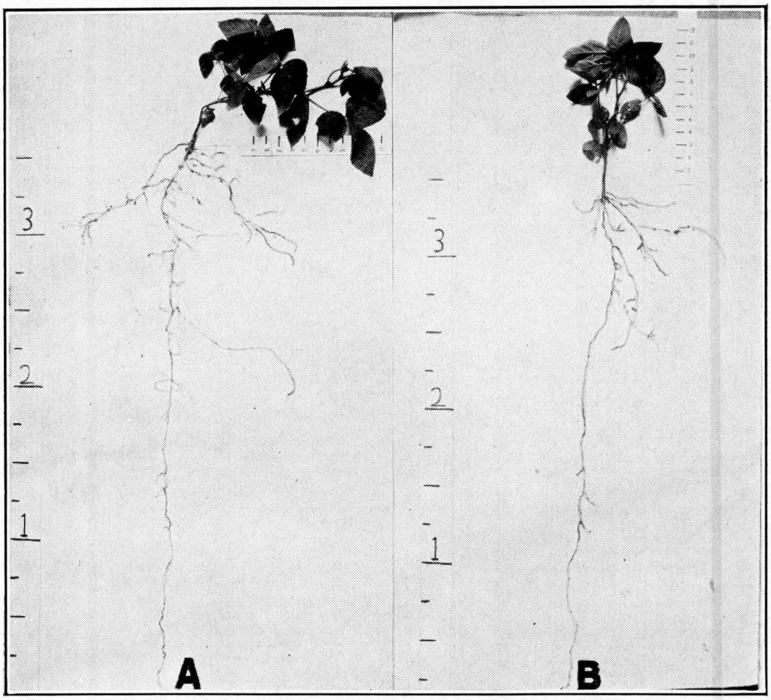

Fig. 9.—Manchu (A) and Peking (B) soybeans, July 16, 57 days after planting

The maximum yields of total tops of Peking were recorded 10 to 15 days later (5878 pounds per acre in 1925, 6122 pounds per acre in 1926). The Peking variety holds its leaves longer than does Manchu, with the result that the maximum of total tops occurred later in the life of the plant than in the Manchu. At the time of maximum yield of total tops, the stems and leaves of both varieties had begun to decrease in weight and the seed was about one-half or more grown. The question of when to cut for hay is considered later, in the discussion of nitrogen content.

Manchu and Peking have been compared as to hay production in the discussion of rate and date of planting. (See Table 4). They are compared again as to yields of total tops on successive harvest dates in Table 12.

A question sometimes asked by growers is: "When an early variety has reached the hay stage, would not a later so-called hay variety harvested at the same time produce just as much hay and hay of better quality because of smaller pods and possibly less fiber?" As far as Manchu and Peking are concerned, the present data answer this question in the negative. Although Peking produced more hay when the two varieties were cut at the same stage of development, Manchu outyielded Peking on any harvest date up to September 10. With one exception, Peking outyielded Manchu when harvested after this date, the difference in favor of Peking being larger for the later sowings.

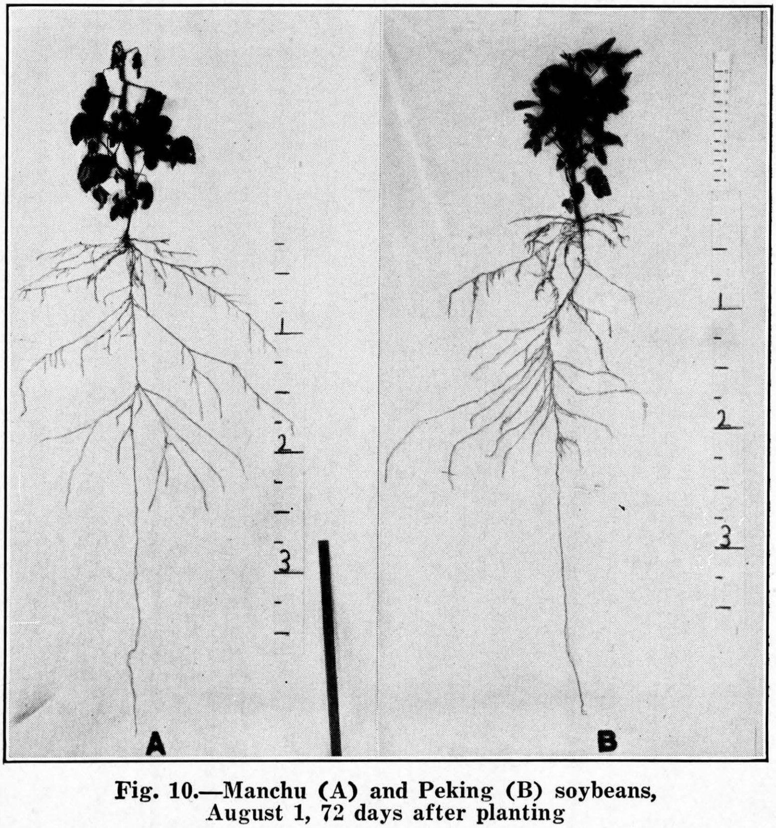

Fig. 10.—Manchu (A) and Peking (B) soybeans, August 1, 72 days after planting

Feed constituents of the tops of the two varieties harvested on August 31 are given in Table 3. At this harvest date, the Manchu variety had reached the hay stage and Peking was approaching it. Differences in the maturity of the two varieties no doubt explain the lower protein and fat content of Peking. It appears that

Peking has more fiber than Manchu even though less mature. Data of Stemple (20) show an increase of fiber as soybean plants mature. The stems of both varieties contain over twice as much fiber as the leaves or pods. The pods at this stage have a little more fiber than the leaves. As indicated by the nitrogen analyses discussed later, the leaves contain more protein than the stems but less than the pods and beans. The total ash is higher in the leaves than in either stems, or pods and beans.

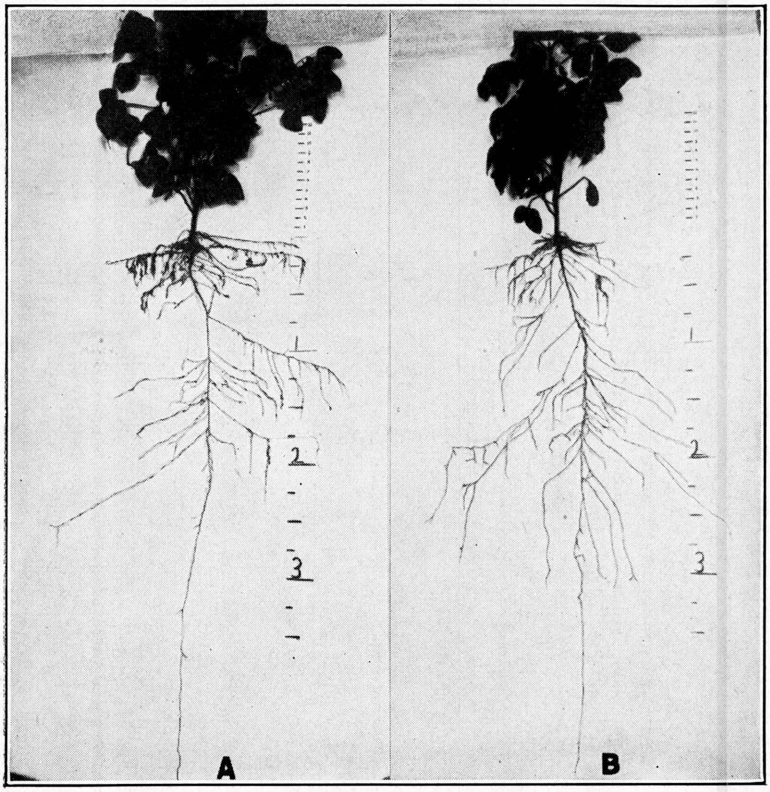

Fig. 11.—Manchu (A) and Peking (B) soybeans, August 15, 87 days after planting

These analyses compare fairly well with those reported by Bechdel (3), Evvard (7), and Henry and Morrison (10), considering probable differences in stages of maturity and differences in location of plantings.

The percentage of nitrogen in plant parts. *Total tops.*—Data on percentage of nitrogen in the plant parts are presented in Tables 13 and 14 and Figure 13. The content of nitrogen in the total tops of each of the two varieties 20 to 30 days after emergence was approximately 3.6 per cent (2-year average). This percentage decreased steadily until the beginning of seed formation to about 2.9 in Manchu and 2.6 in Peking. As the seed formed the percentage of nitrogen in total tops increased to over 3.0 at the time of maturity.

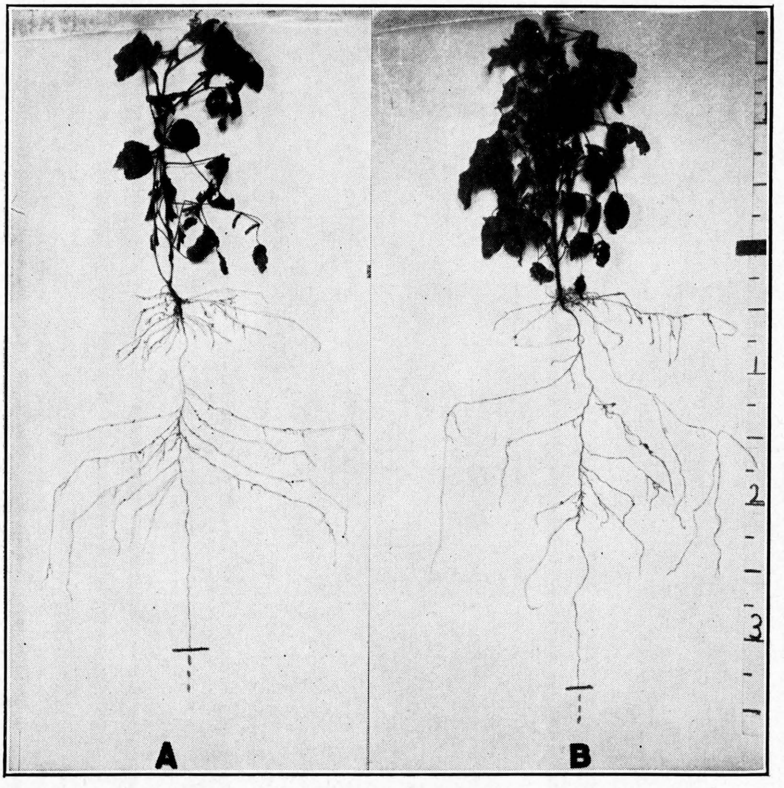

Fig. 12.—Manchu (A) and Peking (B) soybeans, September 9, 111 days after planting

Similar percentages and a similar trend in the percentage of nitrogen in soybeans were reported by Metzger et al. (16). Uhland (22), however, found no increase in the percentage of nitrogen as the plants matured.

Stems and leaves; pods and seed.—The percentage of nitrogen in the leaves of both Manchu and Peking was higher than that of the stems throughout the season. The seasonal average percentages (all percentages recorded in 2 years) of nitrogen for the two varieties were: Manchu stems 1.83, leaves 3.35; Peking stems 1.85, leaves 3.29. Apparently, there is no varietal difference in nitrogen content between these two varieties. The difference between stem and leaf nitrogen remains fairly constant throughout the season, both decreasing at about the same rate. This is shown by the nearly parallel curves for stems and leaves, Figure 13. The percentage of nitrogen in the leaves of Manchu decreased from approximately 4.0 in June to 2.37 at maturity, in the leaves of Peking from about 4.0 to 2.32 during a similar period. The percentage of nitrogen in the stems of Manchu decreased from about 2.8 on July 1 to 0.7 at maturity; the corresponding figures for Peking were 2.6 and 1.0, respectively. These decreases in percentage of nitrogen in

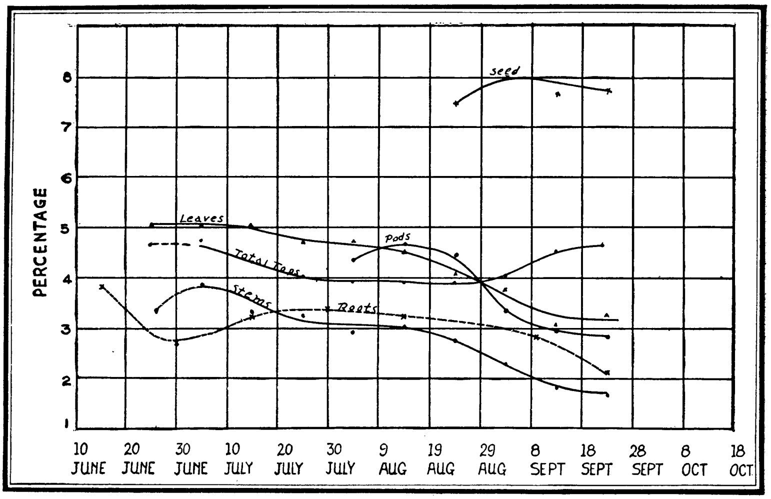

Fig. 13.—Content of nitrogen in Manchu Soybeans
- - - - 1 year ——— 2-year average

leaves and stems indicate a translocation of nitrogen to the seed. A varietal difference is suggested by the slightly lower final percentage of nitrogen in the stems and leaves of Manchu. The percentage of nitrogen in the pods of the two varieties is similar. The maximum nitrogen content of about 3.6 per cent in the pods occurred when the beans were beginning to form and the minimum of about 2.0 per cent at maturity. It is probable that at the time of the maximum percentage of nitrogen the pods contained small beans relatively high in nitrogen and that the percentage given here (3.6) for the pods is high. The decrease in the percentage of nitrogen indicates a translocation of material from the pod to the seed. Manchu seed appears to be slightly higher in nitrogen than

Peking seed, although the significance of this difference is questionable. There was a decrease in the nitrogen content of the seed of both varieties as it finally matured, indicating a continued storage of non-protein constituents.

Roots.—Data on the content of nitrogen in the roots of soybeans are available for 1926 only. On June 15, 30 days after sowing, the percentages for Manchu and Peking were 2.83 and 3.09, respectively. After this date the percentage of nitrogen in the roots of Manchu decreased to 1.75 on about July 1 and that in Peking roots to 1.9 on about July 16. Following these low percentages there was apparently a rise until early in August, at which time the percentages for the two varieties were 2.38 and 2.20, respectively. Following these high points there was a progressive decrease in the percentage of nitrogen in the roots of both varieties. At maturity Manchu roots contained 1.16 per cent and Peking roots 0.98 per cent of nitrogen.

TABLE 13.—Nitrogen Content of Soybeans Grown in Soil "Cans"

Planted May 20, 1926

Date	Days after planting	Manchu		Peking	
		Roots	Tops	Roots	Tops
		Pct.	*Pct.*	*Pct.*	*Pct.*
June 15	28	2.83	3.31	3.09	4.14
July 1	41	1.75	2.83	1.94	2.59
July 16	56	2.21	2.98	1.90	2.65
Aug. 1	72	2.38	3.04	2.20	2.35
Aug. 15	87	2.23	3.07	1.90	2.76
Sept. 9	111	1.82	3.66	1.16	2.80
Oct. 13	145	1.16	4.74	0.98	2.80

Whether the first decrease in percentage of nitrogen in the roots after June 15 would occur every year is open to question. This decrease coincides in time with the grand period of root growth and the beginning of rapid top growth, however, and suggests a rapid use of nitrogen in extension of the root system and the growth of tops. The later decrease in the content of nitrogen in the roots after August 16th indicates a transfer to the upper portions of the plant, since there is little increase in weight of roots after this date. The percentages of nitrogen reported here for 1926 are lower than those reported for the same year in Part II of this bulletin. No doubt, differences in soil, location, variety, and season affect the nitrogen content of the plant. Lipman et al. (15) report percentages of nitrogen in the roots of soybeans grown in pots filled with soil, which are very similar to those obtained in these studies. Piper and Morse (19) report a lower percentage, as does Erdman (6).

TABLE 14.—Content of Nitrogen in Manchu and Peking Soybeans

Manchu

Dates and rates	Stage of growth	Stems			Leaves			Pods			Seeds			Total tops
		1925	1926	Av.	1925	1926	Av.	1925	1926	Av.	1925	1926	Av.	
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
June 26														
Thick	Plants 16 in. to 18 in. high.	2.07	......	......	4.00	......	......	......	......	......	......	......	......	......
Medium		2.47	......	......	4.23	......	......	......	......	......	......	......	......	......
Thin		2.65	......	......	4.02	......	......	......	......	......	......	......	......	......
Average		2.39	......	2.39	4.08	......	4.08	......	......	......	......	......	......	3.62
July 1–9														
Thick		......	2.56	......	......	3.54	......	......	......	......	......	......	......	......
Medium		3.00	2.79	2.90	4.27	3.94	4.11	......	......	......	......	......	......	......
Thin		2.84	2.79	2.82	4.30	3.79	4.05	......	......	......	......	......	......	......
Average		2.92	2.71	2.86	4.29	3.76	4.03	......	......	......	......	......	......	3.71
July 11–20														
Thick	Beginning to bloom.	2.19	1.83	2.01	3.88	3.64	3.76	......	......	......	......	......	......	......
Medium		2.70	2.04	2.37	4.16	4.18	4.17	......	......	......	......	......	......	......
Thin		2.79	2.34	2.57	4.16	3.99	4.08	......	......	......	......	......	......	......
Average		2.56	2.07	2.32	4.07	3.94	4.01	......	......	......	......	......	......	3.34
July 22–30														
Thick	Blooming.	1.98	1.80	1.89	3.73	3.50	3.62	......	......	......	......	......	......	......
Medium		3.31	2.05	2.68	3.99	3.25	3.62	......	......	......	......	......	......	......
Thin		2.12	2.09	2.11	4.00	3.67	3.84	......	......	......	......	......	......	......
Average		2.47	1.98	2.23	3.91	3.47	3.69	......	......	......	......	......	......	3.07
Aug. 1–10														
Thick	Pods beginning to form.	......	2.00	......	......	3.29	......	......	3.28	......	......	......	......	......
Medium		1.89	1.94	1.92	3.95	3.43	3.69	......	3.42	......	......	......	......	......
Thin		......	1.97	......	......	3.60	......	......	3.31	......	......	......	......	......
Average		......	1.97	1.93	......	3.44	3.70	......	3.34	3.34	......	......	......	2.96

TABLE 14.—Content of Nitrogen in Manchu and Peking Soybeans.—Continued

Manchu

Dates and rates	Stage of growth	Stems			Leaves			Pods			Seeds			Total tops
		1925	1926	Av.	1925	1926	Av.	1925	1926	Av.	1925	1926	Av.	
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Aug. 10–20														
Thick	Pods formed.	....	2.30	....	....	3.38	....	....	4.38	....	....	....	....	....
Medium		1.76	2.27	2.02	3.60	3.24	3.42	3.12	3.95	3.54	....	....	....	....
Thin		....	2.19	....	....	3.48	....	....	4.21	....	....	....	....	....
Average		....	2.29	2.03	....	3.37	3.49	....	4.18	3.65	....	....	....	2.93
Aug. 20–31														
Thick	Seed forming.	....	1.99	....	....	2.92	....	....	3.39	....	....	6.37	....	....
Medium		1.72	1.82	1.77	3.36	2.93	3.15	3.61	3.36	3.49	....	6.45	....	....
Thin		....	1.68	....	....	2.96	....	....	2.92	....	....	6.66	....	....
Average		....	1.83	1.78	....	2.94	3.15	....	3.22	3.42	....	6.49	6.49	2.97
Aug. 31–Sept. 9														
Thick	Seed ½ grown.	1.48	1.24	1.36	3.17	3.03	3.10	2.19	3.05	2.62	6.43	6.84	6.64	....
Medium		1.30	1.16	1.23	2.77	2.49	2.63	2.47	2.52	2.50	6.52	7.18	6.85	....
Thin		1.48	1.03	1.26	2.79	2.50	2.65	1.88	2.14	2.01	6.46	7.15	6.81	....
Average		1.42	1.14	1.28	2.91	2.67	2.79	2.18	2.57	2.38	6.47	7.06	6.77	3.07
Sept. 9–22														
Thick	Seed full size; leaves falling.	....	.94	....	....	2.23	....	....	2.52	....	....	6.94	....	....
Medium		.85	.87	.86	1.76	2.45	2.11	1.78	2.16	1.97	6.65	6.92	6.79	....
Thin		....	.64	....	....	2.88	....	....	1.85	....	....	5.81	....	....
Average		....	.82	.84	....	2.52	2.14	....	2.18	1.98	....	6.56	6.61	3.48
Sept. 22–Oct. 1														
Thick	¼ to ½ ripe.	.92	.85	.89	2.44	2.73	2.59	1.88	1.99	1.94	6.65	7.04	6.84	....
Medium		.58	.65	.62	2.22	2.39	2.31	1.62	1.83	1.73	6.71	6.69	6.70	....
Thin		.49	.72	.62	2.16	2.26	2.21	....	1.89	....	....	6.53	....	....
Average		.66	.74	.70	2.27	2.46	2.37	1.75	1.90	1.83	6.68	6.75	6.72	3.65
Average of all dates		....	....	1.83	....	....	3.55	....	....	2.77	....	....	6.60	3.28

TABLE 14.—Content of Nitrogen in Manchu and Peking Soybeans.—Continued

Peking

Dates and rates	Stage of growth	Stems 1925	Stems 1926	Stems Av.	Leaves 1925	Leaves 1926	Leaves Av.	Pods 1925	Pods 1926	Pods Av.	Seeds 1925	Seeds 1926	Seeds Av.	Total tops
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
June 26														
Thick	Plants 8 in. high.	2.40			3.80									
Medium														
Thin		2.80			4.09									
Average		2.60		2.60	3.95		3.95							3.67
July 1–9														
Thick	Plants 12 to 16 in. high.	2.61	2.23	2.42	4.12	3.07	3.60							
Medium		2.68	2.71	2.70	3.96	3.96	3.96							
Thin		2.93	2.39	2.66	3.94	3.63	3.79							
Average		2.74	2.44	2.59	4.01	3.55	3.78							3.48
July 11–20														
Thick		2.38	2.12	2.25	3.33	3.40	3.37							
Medium		2.43	2.15	2.29	3.69	3.59	3.64							
Thin		2.57	2.27	2.42	3.74	3.54	3.64							
Average		2.46	2.18	2.32	3.59	3.51	3.55							3.16
July 20–30														
Thick		2.06	1.65	1.86	3.67	2.96	3.32							
Medium		2.22	1.75	1.99	3.74	3.65	3.70							
Thin		2.36	2.39	2.38	4.04	3.64	3.84							
Average		2 21	1.93	2.07	3.82	3.42	3.62							3.23
Aug. 1–10														
Thick	Buds.		1.75			2.96								
Medium		1.69	1.75	1.72	3.67	3.07	3.37							
Thin			2.13			3.40								
Average			1.88	1.79		3.14	3.41							2.87

TABLE 14.—Content of Nitrogen in Manchu and Peking Soybeans.—Concluded

Peking

Dates and rates	Stage of growth	Stems 1925	Stems 1926	Stems Av.	Leaves 1925	Leaves 1926	Leaves Av.	Pods 1925	Pods 1926	Pods Av.	Seeds 1925	Seeds 1926	Seeds Av.	Total tops
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Aug. 10–20														
Medium	Bloom to full bloom.	1.83	1.82	1.83	3.53	3.23	3.38	...	...	...	...	...	...	2.75
Aug. 20–31														
Thick	Pods forming.	...	...	...	...	...	...	...	...	...	...	...	...	...
Medium		1.75*	1.55	1.65	3.19	3.05	3.12	...	3.57	...	...	...	...	...
Thin		...	1.76	...	...	...	...	...	...	...	...	...	...	...
Average		...	1.66	1.71	...	...	3.12	...	...	3.57	...	...	...	2.65
Aug. 31–Sept. 10														
Thick	Seeds forming.	1.47	...	...	2.68	...	...	...	...	...	...	...	...	...
Medium		1.58	1.26	1.42	2.94	3.27	3.11	...	2.73	...	...	6.88	...	...
Thin		1.97	...	...	3.16	...	...	...	...	...	...	...	...	...
Average		1.67	...	1.47	2.93	...	3.10	...	...	2.73	...	...	6.88	2.58
Sept. 10–22														
Thick	Seed ¼ to ½ grown.	...	...	...	...	...	...	...	...	...	...	...	...	...
Medium		1.48	.78	1.13	2.72	2.60	2.66	2.89	1.94	2.42	6.60	6.40	6.50	...
Thin		...	...	...	...	...	...	...	1.91	...	...	6.52	...	...
Average		...	...	1.13	...	...	2.66	...	1.93	2.41	...	6.46	6.53	2.77
Sept. 22–Oct. 1														
Thick	Seed full grown to ripening.	1.09	...	...	2.26	...	...	1.81	...	...	...	...	...	...
Medium		.95	.94	.95	2.58	2.22	2.40	1.86	1.99	1.93	6.20	5.90	6.05	...
Thin		1.17	...	...	2.43	...	...	1.69	...	...	...	...	...	...
Average		1.07	...	1.01	2.42	...	2.32	1.79	...	1.89	...	...	6.05	3.24
Average of all dates		...	...	1.85	...	...	3.29	...	...	2.65	...	...	6.49	3.04

*Estimated.

Pounds of nitrogen per acre in plant parts.—Data on yields of nitrogen per acre in the various plant parts are given in Tables 15 and 16 and are presented graphically in Figure 14. The nitrogen yields for Peking in 1926 are probably low, comparatively, as they are computed on yields from medium and thin rates of planting; whereas the Manchu nitrogen yields are based on harvests from the three rates of planting. Nitrogen yields in the roots are computed from data on soybeans grown in soil cans in 1926.

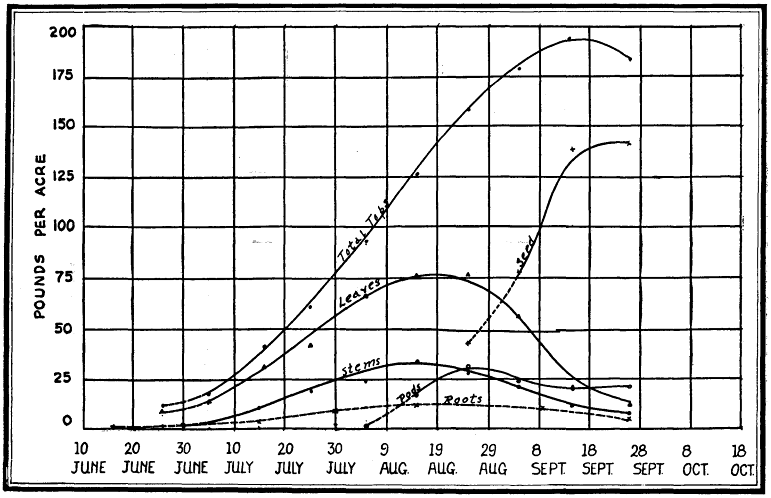

Fig. 14.—Acre yields of nitrogen in Manchu Soybeans

The two varieties produced similar yields of nitrogen in the stems and leaves. Both Manchu and Peking produced a little over 90 pounds per acre of nitrogen in the leaves in 1925 and close to 70 pounds in 1926, and between 30 and 35 pounds per acre in the stems in both years. These maximum yields were reached in Manchu between the 15th and the 20th of August and in Peking about 10 days later, while seed was forming rapidly and before many leaves were lost. After reaching the maximum yield, the nitrogen per acre in the stems and leaves decreased rapidly as the plants matured. This decrease was, no doubt, largely caused by the loss of leaves. Since Manchu loses its leaves more rapidly than Peking, the nitrogen yields decrease more rapidly. However, some of the decrease in the amount of nitrogen in the leaves occurred before leaf fall began. This fact, together with a decrease in the percentage of nitrogen in the leaves, indicates a movement of nitrogen from the leaves. The decrease of nitrogen in the stems and the decrease in weight of stems previously mentioned also indicate a

TABLE 15.—Acre Yields of Nitrogen and Protein in Manchu Soybeans

Sown May 15

Date	Stage of growth	Stems			Leaves			Pods			Seeds			Total tops			Averaged to date of harvest		Protein per acre 2-year av.
		1925	1926	Av.	1925	1926	Av.	1925	1926	Av.	1925	1926	Av.	1925	1926	Av.	Date	Av.	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*		*Lb.*	*Lb.*
June 26	....	2.2	......	(2.2)	9.6	......	(9.6)	......	......	......	....	....	....	11.8	....	11.8	June 26.......	11.8	73.8
July 1-10	....	3.8	3.9	3.9	16.6	12.0	14.3	......	......	......	....	....	....	20.4	15.9	18.2	July 1.......	20.4	113.5
July 10-20	....	10.8	10.1	10.5	32.3	28.0	30.2	......	......	......	....	....	....	43.1	38.1	40.6	July 9-11....	29.2	253.8
July 20-31	....	22.2	15.8	19.0	52.4	31.6	42.0	......	......	......	....	....	....	74.6	47.4	61.0	July 20-22....	56.4	381.3
Aug. 1-10	Buds	23.4	26.4	24.9	76.8	57.2	67.0	......	1.2	......	....	....	....	100.2	84.8	92.5	July 30-Aug. 1	73.8	578.2
Aug. 10-20	Early bloom	31.2	35.0	33.1	83.2	68.0	75.6	13.4	20.4	16.9	....	....	....	127.8	123.4	125.6	Aug. 10.......	106.3	785.1
Aug. 20-31	Pods forming	27.4	27.9	27.7	93.4	59.5	76.5	33.3	30.9	32.1	....	44.2	....	154.1	162.5	158.3	Aug. 20.......	138.8	989.4
Sept. 1-10	Pods formed	26.4	15.4	20.9	66.8	45.6	56.2	19.8	28.1	24.0	64.2	91.0	77.6	177.2	180.1	178.7	Aug. 31.......	169.9	1116.6
Sept. 10-20	Seeds forming	13.7	10.0	11.9	22.0	22.6	22.3	18.3	22.8	20.6	145.5	132.9	139.2	199.5	188.3	193.9	Sept. 10.......	189.8	1211.9
Sept. 20-31	Ripening	7.7	9.5	8.6	14.1	11.9	13.0	19.2	23.7	21.5	135.5	144.7	140.1	176.5	189.8	183.2	Sept. 21-22....	182.4	1144.7
																	Oct. 1.......	189.8	....

translocation of nitrogen to the seed. The nitrogen in the pods of Manchu reached a maximum of approximately 30 pounds per acre about 5 to 10 days later than that in the leaves. A maximum for the nitrogen in Peking pods also occurred about 10 days later than the maximum was recorded in the leaves. (Probably the nitrogen in the pods recorded on the second dates is high because of the presence of seed too small to thresh out.) The nitrogen in the pods, like that of the stems, also decreases as maturity approaches. The pounds of nitrogen per acre in the seed present the steepest curve. The maximum in the Manchu seed is higher and is reached earlier than in Peking.

TABLE 16.—Acre Yields of Nitrogen and Protein in Peking Soybeans†

Sown May 15

Date of harvest	Stems		Leaves		Pods		Seeds		Total tops		Protein per acre
	1925	1926	1925	1926	1925	1926	1925	1926	1925	1926	1926
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
June 26	1.5	......	8.2	......	......	......	....	....	9.7	....	....
July 1	2.4	......	9.9	......	......	......	....	....	12.3	....	....
July 9–11	7.0	3.9	26.3	13.8	......	......	....	....	33.3	17.7	110.6
July 20–22	12.6	8.4	50.3	23.2	......	......	....	....	62.9	31.6	197.5
July 30–Aug. 1	14.6	11.0	68.1	32.6	......	......	....	....	82.7	43.6	272.5
Aug. 10	23.2	16.9	75.0	48.8	......	......	....	....	98.2	65.7	410.6
Aug. 20	28.0	23.3	94.0	60.7	......	......	....	....	122.0	84.0	525.0
Aug. 31	35.8	30.1	91.8	73.0	......	6.9	....	....	127.6	110.0	687.5
Sept. 10	28.9	21.9	77.7	72.4	17.1	31.7	9.5	18.1	133.2	144.1	900.6
Sept. 21–22	17.2	11.4	64.7	43.8	13.4	25.8	52.5	106.0	147.8	187.0	1168.8
Oct. 1	......	13.4	......	41.2	......	24.6	....	102.0	....	181.2	1132.5
Oct. 10	15.2*	......	51.0*	......	14.3*	......	122.7	....	203.2	....	....

*From estimated plant yields.

†Because of large differences in rates of development for the 2 years and because of the lack of complete data for the later harvest dates, 2-year averages are omitted.

The nitrogen in the total tops of Manchu reached a high point early in September and that of Peking several days later. It is of interest to note that from 60 to 70 per cent of the nitrogen per acre in total tops at maturity is in the seed.

The nitrogen per acre in the roots of both Manchu and Peking in 1926 increased until the middle of August, at which time a yield of approximately 12 pounds was recorded for both varieties. After this date there occurred a decrease. Wiancko et al. (27) report 109 pounds of nitrogen in soybean roots and 81.8 pounds in the tops.

The acre yields of protein (N x 6.25) are also presented in Table 15 and the percentages of protein in Table 17. It is of interest to note that maximum protein production of both varieties amounts to over 1100 pounds per acre.

When should soybeans be cut for hay?—It will be noted that both the yield and percentage of nitrogen in the total tops of soybeans rise from just before seed formation until the plants are nearly mature. The yield of total tops reached a maximum about August 20 or September 1, depending on variety. The yields of leaves and protein in the leaves both reached a high point shortly after the beginning of seed formation.

TABLE 17.—Acre Yields of Nitrogen in the Roots of Soybeans§

(1926)

Date of harvest	Days after planting	Manchu			Peking		
		Roots per acre*	Nitrogen†	Nitrogen per acre	Roots per acre	Nitrogen	Nitrogen per acre
		Lb.	*Per cent*	*Lb.*	*Lb.*	*Per cent*	*Lb.*
June 15	31	26	2.83	.74	28	3.09	1.09
July 1	46	137	1.75	2.40	96	1.94	1.86
July 15	61	195	2.21	4.30	171	1.90	3.25
Aug. 1	76	406	2.38	9.66	413	2.20	9.09
Aug. 15	91	536	2.23	11.95	627	1.90	11.91
Sept. 9	117	591	1.82	10.75	758	1.16	8.79
Oct. 1‡	138	437	1.16	5.07	631	.98	6.18

*From Table 11, 1926 data.
†From Table 13.
‡Yields from Oct. 1 harvest; percentages from Oct. 13 harvest.
§Data are for soybeans grown in soil "cans".

If total protein alone is considered the crop should be allowed to become nearly mature before being cut for hay. But, at this time, the yield of leaves has declined materially and the beans in the pods are so large as to dry out slowly, thus presenting curing difficulties.

If quality of hay is considered, it should be cut when the leaves are at their maximum. At this time, mineral content in the leaves is nearly at its maximum, and the percentage of protein in leaves and pods is still fairly high.

Fortunately, this stage in leaf development comes when the pods are from one-half to full grown and the seeds are forming. It would seem then that the best time to cut for hay is when the seed is forming but is still small enough to dry out readily. Cutting at this time also tends to bring the harvest in good haying weather.

The mineral constituents in soybeans.—Data on the mineral constituents of soybeans are presented in Tables 19 and 20. Although the data are for one year only, certain trends are indicated in the various plant parts.

With the exception of calcium in the leaves, the percentage of all mineral elements decreased in the various plant parts and in total tops of both varieties with the age of the plants. Metzger et al. (16) reports a decrease in total ash in Hollybrook soybeans from 14.12 in plants 30 days old to 7.23 in plants 130 days old.

TABLE 18.—Content of Protein in Soybean Tops

Planted May 15

Date of harvest	Days after emergence	Manchu				Peking			
		Approx. stage of maturity	1925	1926	Average	Approx. stage of maturity	1925	1926	Average
			Per cent	*Per cent*	*Per cent*		*Per cent*	*Per cent*	*Per cent*
June 26	32	....	22.6	....	....	....	22.9	....	....
July 1	36	....	24.8	....	....	....	22.9	....	....
July 9–10	45	....	22.4	21.6	22.0	....	20.6	20.6	20.6
July 20–23	56	Blooming	20.9	19.8	20.4	....	21.0	18.8	19.9
July 30–Aug. 1	66	Pods formed	19.9	17.5	18.7	....	19.0	17.5	18.3
Aug. 10	77	Seeds forming	17.8	17.2	17.5	Blooming	17.9	16.9	17.4
Aug. 20	87	....	17.7	18.9	18.3	Pods forming	17.1	16.5	16.8
Aug. 31	98	Seeds ½ formed	18.1	19.4	18.8	Seeds forming	15.0	16.1	15.6
Sept. 10	108	....	20.9	20.3	20.6	Seeds ¼ formed	15.3	17.3	16.3
Sept. 21–22	119	Nearly mature	22.6	22.7	22.7	....	21.9	19.3	20.6
Oct. 1	128	Past mature	....	23.0	....	Mature	....	18.7	....

In general, the leaves have a higher mineral content than the stems. An apparent exception is found in the potassium content for Manchu on June 26. This exception may be due to analytical error.

TABLE 19.—Mineral Content of Soybeans Grown in "Cans"

(1926)

Date and plant part	Calcium Per cent	Magnesium Per cent	Potassium Per cent	Phosphorus Per cent
Manchu				
August 15				
Roots	.38	.51	.85	.28
Tops	.94	.69	1.20	.34
October 13				
Roots	.42	.38	.55	.13
Tops	.61	.91	1.51	.48
Peking				
September 9				
Roots	.41	.44	.64	.16
Tops	.92	.65	1.17	.31
October 13				
Roots	.43	.47	.60	.06
Tops	.63	.39	1.48	.36

The percentage of potassium in both leaves and stems was much higher on the first harvest date (June 26) than that of any other mineral element and decreased more rapidly in the early stages of growth. The percentages of potassium in Manchu were: June 26—stems 3.55, leaves 2.26; August 1—stems .94, leaves .95; September 21—stems .51, leaves .89. Apparently, potassium decreases more rapidly in the stems than in the leaves. Since the stems do not increase as rapidly in weight as do the leaves, there is indicated a translocation of potassium from the stems to other plant parts. Another point to be noted is that the seed contains a much higher percentage of potassium than of the other mineral elements. The percentage of potassium in the total tops at the end of the season remains higher than that of the calcium or any other element because of the high percentage in the seed.

The percentage of calcium in the total tops of Manchu decreased rather slowly from 1.87 on June 26 to 1.36 on August 31. By September it had decreased to .65, there being a very low percentage of this element in the seed. In the leaves the percentage of calcium fluctuated, rising to a maximum of a little over 2.0 at the beginning of seed formation, after which it decreased. In the stems there was a gradual decrease in calcium from 1.3 (Manchu) on June 26 to .71 on September 21.

TABLE 20.—Mineral Content of Soybeans

Sown May 15, 1925

Date of sampling	Stems		Leaves		Pods		Seeds		Total tops	
	Manchu Per cent	Peking Per cent	Manchu Per cent	Peking Per cent	Manchu Per cent	Peking Per cent	Manchu Per cent	Peking Per cent	Manchu Per cent	Peking Per cent
Calcium										
June 26	1.30	...	1.97	...	...	...	...	...	1.87	...
July 22	1.05	.99	1.74	1.98	...	...	...	...	1.45	1.69
Aug. 31	.97	.73	2.30	2.00	1.11	...	.19	...	1.36	1.48
Sept. 21	.71	.62	1.73	2.17	.97	1.07	.17	.23	.65	1.22
Magnesium										
June 26	.73	...	.71	...	...	...	...	...	.71	...
July 22	.63	.62	.80	1.00	...	...	...	...	.63	.88
Aug. 31	.67	.70	.82	1.01	.58	...	.19	...	.67	.89
Sept. 21	.43	.61	.69	.88	.60	.66	.22	.25	.43	.67
Potassium										
June 26	3.55	...	2.26	...	...	...	...	...	2.44	...
July 22	...	1.52	1.48	1.57	...	...	...	...	1.16	1.55
Aug. 31	.94	.91	.95	1.19	1.68	...	1.76	...	1.23	1.07
Sept. 21	.50	.62	.89	.92	1.34	1.31	1.59	1.81	1.19	1.03
Phosphorus										
June 26	.30	...	.36	...	...	...	...	...	.34	...
July 22	.31	.24	.36	.32	...	...	...	...	.34	.29
Aug. 31	.15	.21	.24	.29	.27	...	.71	...	.32	.26
Sept. 21	.07	.12	.23	.23	.15	.22	.65	.69	.36	.27

TABLE 21.—Acre Yields of Mineral Elements in Soybeans

Sown May 15, 1925

Date of sampling	Stems		Leaves		Pods		Seeds		Total tops	
	Manchu Lb.	Peking Lb.	Manchu Lb.	Peking Lb.	Manchu Lb.	Peking Lb.	Manchu Lb.	Peking Lb.	Manchu Lb.	Peking Lb.
Calcium										
June 26	.5	....	4.1	....	....	....	....	....	4.6	....
July 22	10.3	4.8	23.2	23.1	....	....	....	....	33.5	27.9
Aug. 31	13.9	15.3	53.2	61.7	11.8	....	2.3	....	81.2	77.0
Sept. 21	8.0	11.7	9.8	50.9	9.3	11.0	3.3	2.1	30.4	75.7
Magnesium										
June 26	.3	....	1.5	....	....	....	....	....	1.8	....
July 22	6.2	3.0	10.7	11.6	....	....	....	....	16.9	14.6
Aug. 31	9.6	14.6	19.0	31.3	6.1	....	2.3	....	37.0	45.9
Sept. 21	4.8	11.5	3.9	20.7	5.7	6.8	4.4	2.3	18.8	41.3
Potassium										
June 26	1.2	....	4.7	....	....	....	....	....	5.9	....
July 22	....	7.3	19.9	18.3	....	....	....	....	26.9	25.6
Aug. 31	13.3	19.1	21.9	36.6	17.9	....	20.5	....	73.6	55.7
Sept. 21	5.6	11.7	5.0	21.7	12.8	13.5	32.0	16.7	55.4	63.6
Phosphorus										
June 26	.1	....	.7	....	....	....	....	....	.8	....
July 22	3.1	1.1	4.8	3.7	....	....	....	....	7.9	4.8
Aug. 31	2.1	4.4	5.6	9.0	2.8	....	8.3	....	18.8	13.4
Sept. 21	.8	2.3	1.3	5.5	1.4	2.3	13.1	6.4	16.6	16.5
Dry weight of plant parts										
June 26	34	....	205	....	....	....	....	....	239	....
July 22	977	480	1337	1166	....	....	....	....	2314	1646
Aug. 31	1423	2092	2315	3087	1063	....	1166	....	5967	5179
Sept. 21	1114	1887	566	2350	960	1029	2006	926	4646	6192

The percentage of phosphorus in the total tops of Manchu tended to decrease slightly from .34 on June 26 to .32 on August 31 and apparently increased as the plants approached maturity. These are small fluctuations but are supported by Austin's data (2). The percentage of phosphorus in the stems decreased more rapidly than that in the leaves.

The percentage of magnesium also decreased more rapidly in the stems than that in the leaves. The percentage of both calcium and magnesium in the seed is comparatively low.

In general, these percentages are higher than those reported by Thatcher (21), but, as reported by Austin (2) and Mitchell et al. (17), soybean plants are found to vary in mineral content when grown on different soil types and with different fertilizer treatments.

The pounds per acre of the mineral elements are given in Table 21. Although the analyses are not sufficiently numerous to indicate definitely when the maximum amounts of the minerals occurred, the maxima of all minerals were recorded on August 31. The leaves carried the greatest amounts of all minerals. Calcium was present in greatest amount on this date, followed closely by potassium. The amount of magnesium was greater than that of phosphorus.

PART II. YIELD AND COMPOSITION OF SOYBEANS AT VARIOUS STAGES OF MATURITY

L. E. THATCHER[1]

Soybeans may be harvested for hay at several stages of maturity. The stage of maturity may affect the yield, quality, and composition of the hay and the weight and composition of the roots and stubble remaining in the soil. The effect of time of harvest upon these factors was investigated at Wooster during the 6-year period 1922 to 1927, inclusive.

METHODS

Thirty permanent plats, one-sixtieth acre in size, were laid out in a 2-year rotation of soybeans and wheat, 15 plats of each crop. Three systematically distributed plats were selected for each of the five dates of harvest; in this report, all plat data are the average of three plats.

The soybeans were drilled solid with a grain drill in rows 8 inches apart, at the rate of 6 to 8 pecks of seed per acre, depending upon the size of seed. Good stands were obtained.

In 1922 and 1923, a mixture of Guelph (Medium Green) and Johnson No. 4 soybeans was used for seed. In 1924, 1925, and 1926, a pure line selection from the Manchuria variety, Ohio No. 20173, was used and in 1927 the Manchu variety was used.

The first harvest of soybeans was made at the time the plants were in full bloom, approximately August 1, and at approximately 15-day intervals thereafter until October 1. The stage of development of the plants at the time of comparable dates of harvest varied somewhat for different seasons and is indicated in Table 1.

The seasons, with the exception of 1925, were fairly normal. In 1925, the soybeans developed early in the season, blooming early and ripening early in the fall. Some loss in seed due to shattering occurred late in September. Killing frost did not occur until October 8, long after the seed crop was ripe. Owing to this favorable weather in the fall, many leaves were active after the seed was ripe, resulting in a slightly increased weight of stems after September 16. The percentage of nitrogen increased in the leaves, pods, and seeds and remained constant in the stems, due, probably, to this

[1]The author is indebted to Mr. C. E. Dike, formerly Assistant Agronomist, for valuable assistance in obtaining the plat data, to Mr. J. W. Ames, Associate, and his co-workers in the Chemistry Division, for the chemical analyses herein reported.

renewal of vegetative growth. In other years, frost occurred on the following dates: September 26, 1922, September 14, 1923, September 24, 1924, September 26, 1926, and September 21, 1927. These September frosts stopped active vegetative development of the plants but did not interfere with the completion of ripening.

TABLE 1.—Stage of Development of Plants on Each Date of Harvest

Periods of harvest				
1st	2d	3d	4th	5th
		1922		
Aug. 1	Aug. 15	Aug. 31	Sept. 16	Oct. 1
Plants full bloom	Pods forming	Small seed forming	Seed ⅔ formed	Seed ripe, leaves falling
		1923		
Aug. 1	Aug. 15	Aug. 31	Sept. 16	Oct. 1
Plants full bloom	Pods forming	Small seed forming	Seed ⅔ formed	Seed ripe, leaves falling
		1924		
Aug. 6	Aug. 18	Aug. 28	Sept. 15	Oct. 1
Plants full bloom	Pods forming	Small seed forming	Seed ½ formed	Seed ripe, leaves falling
		1925		
Aug. 3	Aug. 14	Sept. 1	Sept. 16	Oct. 2
Plants past full bloom	Pods formed	Seed ¾ formed, some leaves falling	Seed almost ripe, leaves falling	Seed ripe, many leaves fallen
		1926		
Aug. 4	Aug. 18	Sept. 3	Sept. 15	Oct. 4
Plants past bloom	Pods ½ formed	Seed ½ formed	Seed ¾ formed	Seed ripe, leaves falling
		1927		
Aug. 9	Aug. 22	Sept. 2	Sept. 19	Oct. 3
Plants full bloom	Pods forming	Small seed forming	Seed ⅔ formed	Seed ripe, leaves falling

At harvest, the green weight of the triplicate plats was obtained, and a sub-sample of 50 pounds was taken for drying. This sample was separated at once into leaves and stems for the early harvests, and, in addition, into pods and seeds for the later ones. These plant parts were dried in an oven, later stored in a dry room in the laboratory, and then allowed to come to equilibrium in moisture content (approximately 7 per cent).

The samples were then weighed, the yields of air-dry material calculated, and the samples ground for chemical analyses. The percentages of nitrogen, phosphorus, potassium, calcium, and magnesium were determined for the several plant parts. Protein was calculated from the nitrogen by using the factor 6.25.

In four years of the six, 1923, 1925, 1926, and 1927, the roots were also sampled by digging 50 plants at each harvest, the plants weighed, and the roots separated from the tops by cutting the stems at the first node. This short stubble was included with the roots. Weight of roots, chemical analyses of roots, etc., are understood to include this 1 or 2 inches of stubble.

Immediately after the last harvest, October 1, a seedbed was prepared by discing, 350 pounds of 16 per cent superphosphate applied, and winter wheat seeded. No fertilizer was used on the soybeans. Inoculation was good, the land having grown soybeans before.

The soil, Wooster silt loam, was in a good state of productivity at the beginning of the test.

RESULTS

YIELDS OF TOTAL TOPS AND OF PLANT PARTS

Table 4 gives the yields per acre on an air-dry basis (about 7 per cent moisture) of total tops, for the separate plant parts (leaves, stems, pods, seeds, and roots) for each year of sampling, for the 6-year average for tops, and for a 4-year average for roots (Fig. 1).

The 6-year average maximum yield of tops was obtained by cutting approximately September 15, the fourth date of harvest, with September 1, the third date, but little lower. The stage of development of the plants covered by this period was from the time the pods were full length with a few small beans formed to the stage when the beans were one-half to three-fourths formed in the pods.

The maximum yield of tops for 1925, an early season, was obtained on the second date of harvest, in 1922, in 1927 on the third date, and in 1923, 1924, and 1926 on the fourth date.

The maximum yield of leaves for the 6-year average was obtained by cutting approximately August 15, the second date, although the third date, about September 1, yielded but little less. The weight of leaves on the fourth date of harvest, the date of maximum total yield, was but 535 pounds per acre less than for the third date. The maximum yield of leaves, on the average, corresponds to the stages of development—"Pods forming" to "Small seed forming". The yield of leaves decreased after this stage of development, due in part to the translocation of material to other parts of the plant and in part to the loss of leaves through shattering as the plants matured. That the loss through translocation is considerable is shown by the composition, as discussed later.

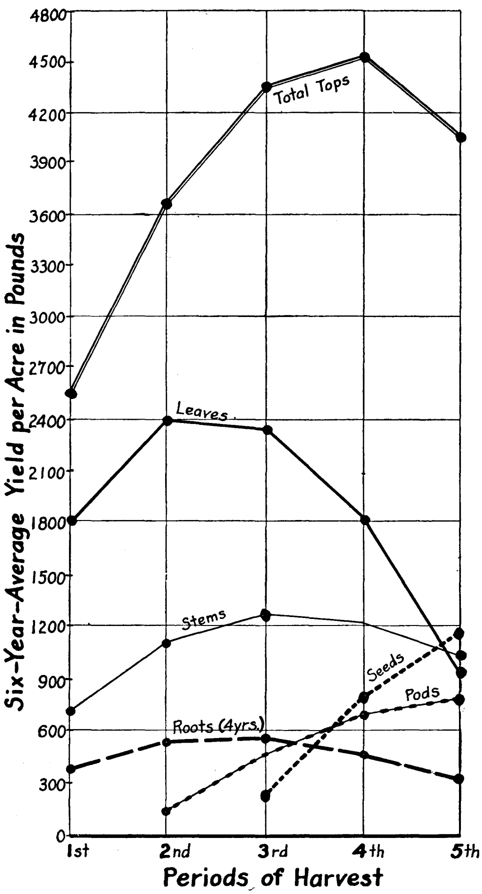

Fig. 1

The leaves made up 71.3, 65.7, 54.0, 40.1, and 25.4 per cent of the total crop for the first to the fifth dates of harvest. In this connection it may be noted that the tentative United States Standards for soybean hay, issued in November 1928, require 40 per cent or more leaves in order to grade No. 1 and 25 per cent or more for No. 2. Hay containing less than 25 per cent of leaves falls into No. 3 grade.

For 3 of the 6 years, the maximum yield of leaves was obtained on the second date of harvest and in 3 years on the third date. In 1925, the plants developed quite early and were shedding leaves by September 1.

The weight of stems followed somewhat the same course as the weight of the leaves, increasing to a maximum until the seed began to form and falling off in weight as the seed developed. The stem evidently functions as a storage place for material that is later moved into the seed. Its chemical composition at the different stages indicates this to be the case.

For the 6-year average, the stems made up, respectively, 28.7, 30.4, 30.2, 27.5, and 26.8 per cent of the total crop harvested on the first to the fifth dates of harvest.

The stem-leaf ratio is of interest since leaves add more to the feeding value of the hay than do the stems. The stem-leaf ratio decreases from the first to the fifth, or last, harvest. For the 6-year average, these ratios are, respectively, 1 : 2.48, 1 : 2.16, 1 : 1.79, 1 : 1.45, and 1 : 0.94.

The weight of pods tended to reach a maximum at the time the seeds were one-half to two-thirds formed, and then either to increase slowly, or, as in 3 years of the 6, to decrease in weight as the seed developed. Translocation of material to the seed is also indicated by the chemical analyses reported later.

For the 6-year average, the pods made up 3.9, 10.4, 15.6, and 19.3 per cent, respectively, of the total crop from the second to the fifth dates of harvest.

The weight of seed increased rapidly during the last month of development. For the 6-year average the seed made up 5.4, 16.8, and 28.4 per cent of the crop on the third, fourth, and fifth dates of harvest, respectively.

The weight of roots was determined for 4 years of the 6. In 1923, the maximum weight of roots per acre was obtained on the sampling date, August 31, at the beginning of seed formation; in 1925, on August 14, at about the same stage of development; in 1926, on September 15, at the time the pods were plump with seed; and in 1927, on September 2, with the beginning of seed formation. For the 4-year average, the weight of the tops was 5.7, 6.2, 6.9, 8.4, and 9.9 times the weight of roots from the first to the fifth dates of harvest. The weight decreased as the seed developed. The top-root ratio toward the end of the season was influenced by leaf fall.

PROTEIN

The percentage and pounds per acre of protein are given in Table 5.

The protein content of the plant parts was calculated from the nitrogen analyses by using the factor 6.25.

Percentage of protein.—The percentage of protein in the crop is influenced by changes in the percentage of protein in the plant parts as they develop, by changes in ratio of plant parts to each other, and by the loss of leaves through shattering upon the approach of maturity.

For the 6-year average, the tendency was for a slight decrease in percentage of protein in the crop from the first harvest to the second harvest and then a slight increase until the fifth, or last, harvest.

In 1922, the percentage of protein in the crop decreased from the first to the fifth harvesting date, with one exception (the second date) which was low.

In 1923, the percentage of protein in the crop decreased for the first four cuttings and then increased for the fifth, or last, cutting. This was caused by the great loss of leaves of relatively low protein content and made the seed, which is high in protein, a larger proportion of the total weight. In 1924, the percentage of protein in the crop reached a maximum on the third date and then dropped to the fifth. The loss of leaves was not excessive that year.

In 1925, the percentage of protein in the crop increased markedly after the first two cuttings. Leaves began to fall early that season, and the seed made up a large proportion of the total weight early in the season. In 1926, the percentage of protein in total tops was high throughout the season; the October 4 cutting was high, due to the loss of leaves and the corresponding increase in proportion of seed to total weight. In 1927, an increase in the percentage of protein for the last two cuttings, due to the great loss of leaves and an increase in the proportion of seed, was again observed.

In 5 of the 6 years, the leaves decreased in percentage of protein with the development of the plant from blooming to ripening. The exception (1925), as has been noted, was an abnormal year, and there was an increase in percentage of protein at the end of the season. The percentage of protein decreased, however, for the other four cutting dates that year.

The stems showed a marked tendency for a reduction in protein content as the seed developed. From blooming to early seed formation there may be an increase in protein, as in 1922, 1924, and 1925, although in the other years this tendency was not apparent.

The immature pods, before seeds formed, were very high in percentage of protein; this rapidly decreased as the seeds developed.

The seeds, for the most part, showed a slight tendency to decrease in percentage of protein with the approach of maturity.

The percentage of protein in the crop is of interest from the feeding standpoint. For the 6-year average, the percentage of protein in the leaves and stems at the third harvest was 15.5 and 9.5, respectively; whereas 2 weeks later, the date of maximum crop yield, the percentage had dropped to 12.6 per cent in the leaves and to 6.8 per cent in the stems. The seeds, which make up a larger part of the hay at the later date of harvest, carried enough more protein to maintain the average protein content of the total tops, in spite of the lower percentage in the leaves and stems. Since the yield of hay harvested about September 1 was but slightly less and the protein content of the plant parts greater than 2 weeks later, the earlier harvest, at which time the seeds are quite small, should be given preference where the feeding value and palatability of the entire crop are of importance. As the plants approach maturity, the stems become woody and unpalatable, and there is also more or less loss of seed in handling the hay. In this connection, it may be pointed out that Willard (28) has shown that the curing of soybean hay becomes more difficult as the beans are allowed to develop in the pods.

Protein per acre.—For the 6-year period, the maximum yield of protein was obtained on the approximate date, September 15 (the fourth harvest), corresponding to the date of maximum crop yield.

In four seasons out of the six, the fourth date of harvest returned the most protein per acre. One year it occurred on the third and one year on the fifth, or last, date of harvest. The corresponding stages of development ranged from the small-seed-forming state to maturity. For the most part, it came at the time the leaves were turning yellow at the base of the plant, and the seeds were two-thirds to fully formed in the pods, the seeds containing about one-half the total protein in the plant.

NITROGEN

Table 6 and Figures 2 and 3 give the percentage and pounds per acre of nitrogen in the plants and for the several plant parts.

Nitrogen per acre.—By comparing the pounds per acre of nitrogen in the plant parts for the several dates of harvest, some evidence of the movement of nitrogen in the plant can be obtained.

The movement in the leaves is difficult to follow because the loss of nitrogen from the plant through the dropping of leaves upon the approach of maturity cannot be distinguished from the loss through translocation. That there is a movement, however, from the leaves to the seed, is indicated by comparing the third and fourth harvests in the 6-year average. On the third date, the average amount was 61.2 pounds per acre and on the fourth date, 39.1 pounds. Only small losses of leaves by dropping had taken place at this time, except in 1925.

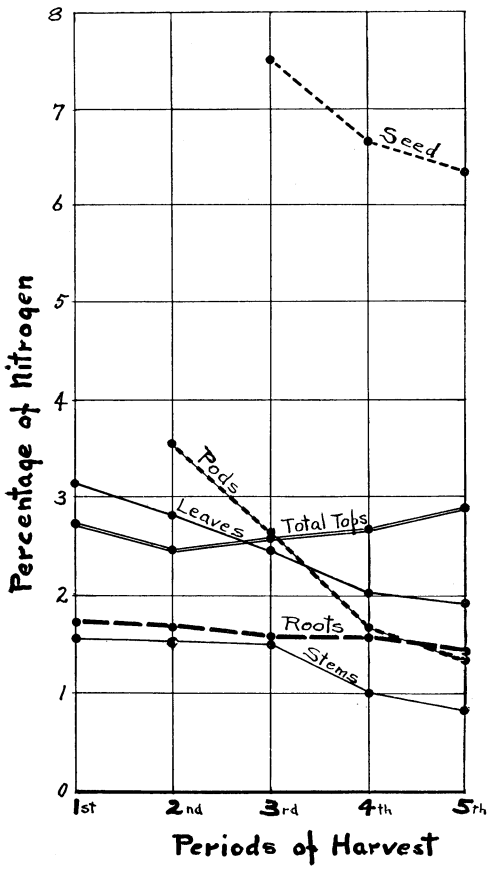

Fig. 2

A study of the data for individual years showed that for each year the nitrogen in the leaves became less after the beginning of seed formation.

The storage of nitrogen in the stems reached a maximum and then declined with seed formation, following closely the storage trend in the leaves. A movement of nitrogen from the stems to the pods and seeds is indicated quite strongly.

The pods in the early stages of development stored much nitrogen, as shown by the amount per acre, as well as by the percentage. The amount stored became less as the seed developed. This trend is shown to best advantage by the data for individual years rather than by the 6-year average.

The storage of nitrogen in the seed increased rapidly with development. At maturity, the 6-year average shows more than half of the nitrogen of the crop stored in the seed.

The storage of nitrogen in the roots, on the average, tended to reach a maximum at about the seed-forming stage. In 1926, however, it came at a later stage, when the pods were plump with seeds.

In all cases, however, the pounds per acre in the roots were less at the last date of harvest than for the period 2 weeks earlier. Part of this loss may have been due to the difficulty of obtaining a satisfactory sample of roots at this time, since the beginning of decay in the small roots and in the nodules had taken place. Part of the loss at the fifth date of harvest, however, may have been due to translocation to the tops, as indicated by the general tendency for pounds per acre of the nitrogen in the roots to become less from the third to the fourth date of harvest. As a 4-year average, the maximum amount of nitrogen in the roots was obtained on the second date of harvest about August 15 and gradually decreased as the plants matured.

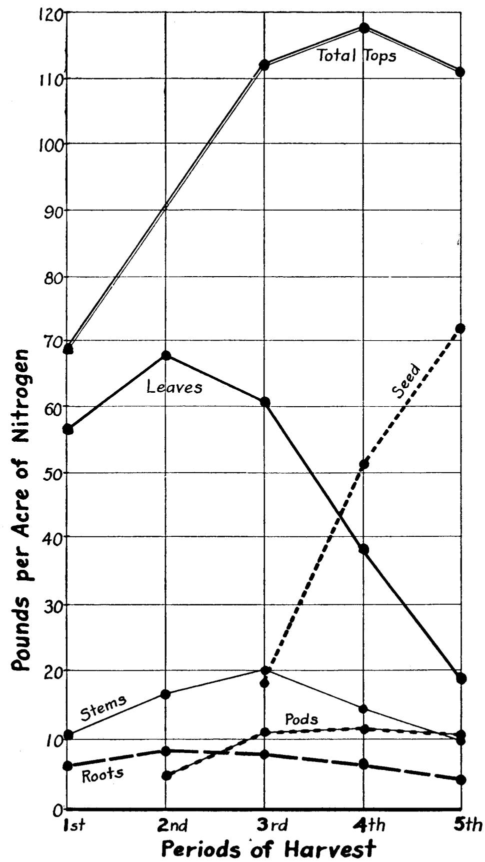

Fig. 3

The ratios of pounds of nitrogen per acre in the roots to that in the tops for the several dates of harvest were as follows:

Pounds per acre nitrogen Ratio roots to tops	Harvests 1st	2nd	3rd	4th	5th
1 to..	10.0	9.7	12.7	17.0	23.0

PHOSPHORUS

Table 7 and Figures 4 and 5 give the percentage and pounds per acre of phosphorus in the crop.

Percentage of phosphorus.—The percentage of phosphorus in the total tops, as shown by the 6-year average, tended to increase from the early to the late dates of harvest. This tendency was not entirely consistent for individual years, however.

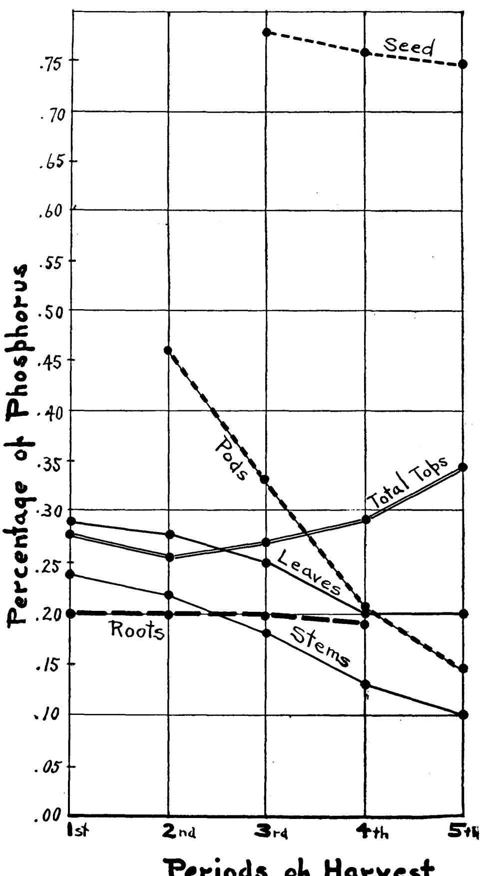

Fig. 4

The percentage of phosphorus in the leaves for the 6-year average showed a tendency to decrease as the harvest became later. The percentages for the first and second dates of harvest were higher in every year than for the fourth and fifth dates, with the exception of the last date in 1925. Evidently, there is a tendency for the percentage of phosphorus in the leaves to decrease with the approach of maturity.

The stems showed a consistent tendency to decrease in percentage of phosphorus as the plants developed and matured. The exceptions were a slight increase for the second cutting in 1924 and for the last cutting in 1925.

The pods also tended to decrease in percentage of phosphorus, with the exception of the last cutting in 1925 and the third in 1927. Immature pods were relatively high in phosphorus.

The seeds had a higher phosphorus content than the other plant parts and the percentage was fairly constant.

The percentage of phosphorus in the roots, on the average, changed but little.

Phosphorus per acre.—The movement of phosphorus in the plant is indicated by the pounds of phosphorus per acre in the different plant parts for the several dates of harvest.

The 6-year average indicates that the amount of phosphorus carried by the total tops increased with the development and maturity of the plant. This varied somewhat with individual years. In 1922, 1924, and 1926, the last date of harvest showed a little less phosphorus per acre than the previous date, and in 1925 a loss began with the third date of harvest. In the other 2 years, the storage increased to the last date.

The leaves increased in phosphorus per acre from the first to the second and third harvests, reaching a maximum at the beginning of pod and seed formation. As the seeds developed, the amount of phosphorus in the leaves and pods decreased; the stems also showed this tendency markedly.

The seeds showed a marked increase in phosphorus per acre as they developed and matured. The actual amounts and relative proportions of phosphorus in the seeds and in the rest of the top (leaves, stems, and pods) for the three dates of harvest for which seed yields have been obtained are given in Table 2.

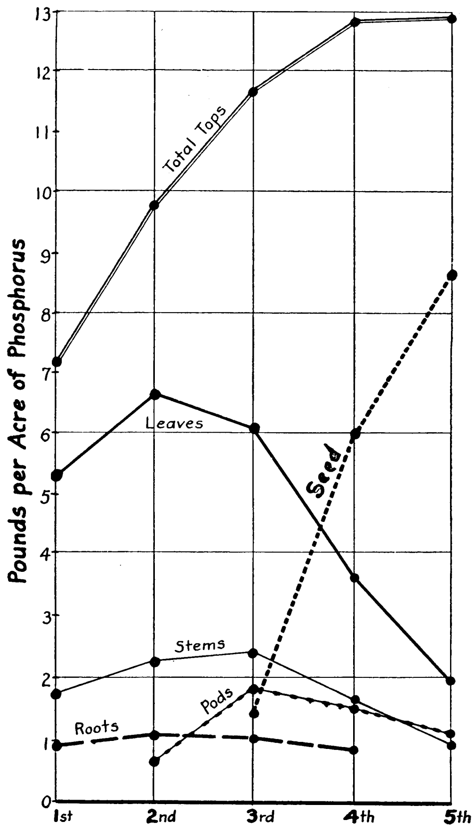

Fig. 5

Soybeans cut about September 1 in the early stages of seed development contained only about one pound less phosphorus per acre than when cut September 15 with seeds one-half to two-thirds formed or when cut October 1 at the ripe stage. At the early stage, however, 84.7 per cent of the phosphorus in the plant was in the leaves, stems, and pods, at the mid-stage 55.0 per cent, and at the last stage 32.3 per cent.

The maximum amount of phosphorus per acre in the roots, on the average, was obtained from about August 15 to September 1, with a tendency for the amount to decrease after this period. However, the differences were small.

TABLE 2.—6-year Average Pounds Phosphorus per Acre and Relative Amounts in Seeds, as Compared to Leaves, Stems, and Pods

Approximate dates cut	Pounds per acre			Per cent of total phosphorus in	
	Seeds	Leaves, stems, and pods	Total	Seeds	Leaves, stems, and pods
Sept. 1	1.8	10.0	11.8	15.3	84.7
Sept. 15	5.8	7.1	12.9	45.0	55.0
Oct. 1	8.8	4.2	13.0	67.7	32.3

The average amounts of phosphorus removed by the crop harvested on the different dates, expressed in terms of phosphoric acid (P_2O_5) and 20% superphosphate fertilizer, are about as follows:

	PHOSPHORIC ACID (P_2O_5)	SUPERPHOSPHATE (20%)
August 1	16.4 pounds	82 pounds
August 15	22.5 pounds	112 pounds
September 1	27.1 pounds	135 pounds
September 15	29.6 pounds	148 pounds
October 1	30.0 pounds	150 pounds

POTASSIUM

Table 8 and Figures 6 and 7 give the percentage and pounds per acre of potassium in the crop.

Percentage of potassium.—For the 6-year average the tendency was for the percentage of potassium to decrease in the total tops from the first to the second cutting, changing but little until the fifth when it increased. This is partly accounted for by the increase in the weight of seeds of relatively high potassium content from the fourth to the fifth cutting dates.

This tendency toward an increase in percentage of potassium in total tops at the end of the season is characteristic of 5 of the 6 years, 1925 being the exception, and may be accounted for by some loss of seed through shattering on the last date of harvest.

The percentage of potassium in the leaves decreased from the first to the last cutting date with a few exceptions; namely, the last cuttings in 1922 and 1923, the second in 1924 (a very slight increase), and the second in 1926.

In the stems, the percentage of potassium decreased from the first to the last cutting with one exception, the third cutting in 1925. The decrease was marked.

The percentage of potassium was high in the immature pods and decreased with the approach of maturity with two exceptions, the fifth cuttings in 1922 and 1923.

The seeds contained a higher percentage of potassium than any of the other plant parts, except the immature pods in 1925 and 1926, and reached a maximum a little before maturity, or about the time the leaves began to turn yellow at the base of the plant.

The roots showed a relatively low percentage of potassium with a tendency to decrease as the plants matured.

Potassium per acre.—The total amount of potassium per acre in the total tops showed a tendency to increase with maturity. There were a few exceptions, which can be accounted for partly by the leaf fall upon the approach of maturity.

The 6-year average showed a gradual increase in amount of potassium per acre in the total tops from the first to the last cutting dates.

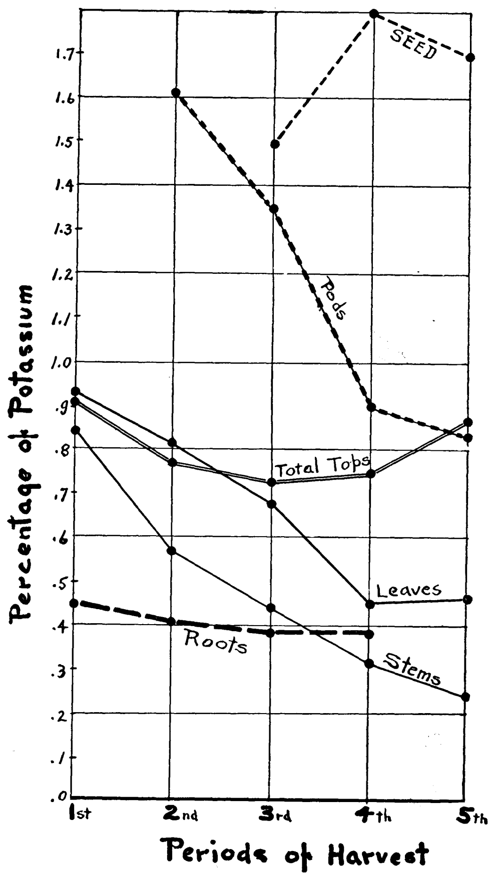

Fig. 6

The translocation of potassium in the plant is indicated by the relative amounts in the several plant parts for each cutting date.

The leaves contained their maximum amount of potassium per acre just previous to seed formation, the amount decreasing rapidly as the seed formed. Part, but not all, of this decrease can be accounted for by leaf fall, which is important only from the fourth to the fifth cutting dates, with the exception of 1925, when the leaves began to fall earlier in the season.

The stems follow very much the same trend as the leaves, showing a marked movement of potassium to the pods and seeds.

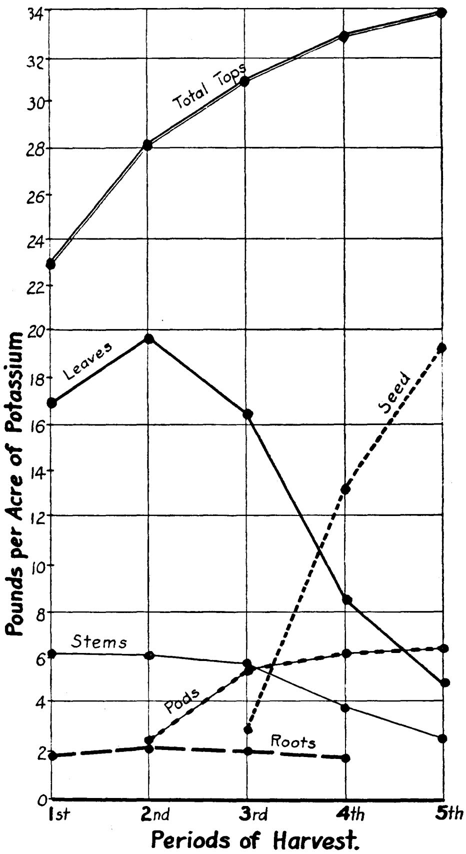

Fig. 7

With the approach of maturity, the pods gained rapidly over the stems in the amount of potassium per acre. The percentage in the pods also remained higher than in the stems. The large amount of potassium in the pods at the last cutting in 1923 seems out of line with the other determinations and has had an influence upon the 6-year average, which shows an increase from the fourth to the fifth cutting dates. On the whole, however, the tendency seems to be for the amount of potassium per acre in the pods to decrease with the ripening of the seeds.

The amount of potassium per acre in the seeds increased with maturity, due to their rapid increase in weight and to their high percentage of potassium. As a 6-year average, the seeds at maturity contained about 58 per cent of the total potassium in the tops, and 2 weeks previous to this about 41 per cent.

The amount of potassium per acre in the roots was small compared to the tops. The general tendency, as indicated by the 4 years of sampling, was for the amount to increase to approximately the beginning of seed formation and then to decrease.

The amounts of potassium removed by the crop for the several dates of harvest, as indicated by the 6-year average, in terms of potash (K_2O) and commercial muriate of potash, are as follows:

	POTASH (K_2O)	MURIATE OF POTASH (50% K_2O)
August 1	28 pounds	56 pounds
August 15	34 pounds	68 pounds
September 1	38 pounds	76 pounds
September 15	39 pounds	78 pounds
October 1	41 pounds	82 pounds

CALCIUM

Table 9 and Figures 8 and 9 give the percentage and pounds per acre of calcium in the crops.

Percentage of calcium.—The percentages of calcium in the total tops for the several dates of harvest fail to show consistency. The data for 1922 and 1923 might suggest a maximum percentage at the beginning of seed formation, followed by a decrease. In 1924, 1925, 1926, and 1927, however, the decrease was gradual from the first to the last cutting date.

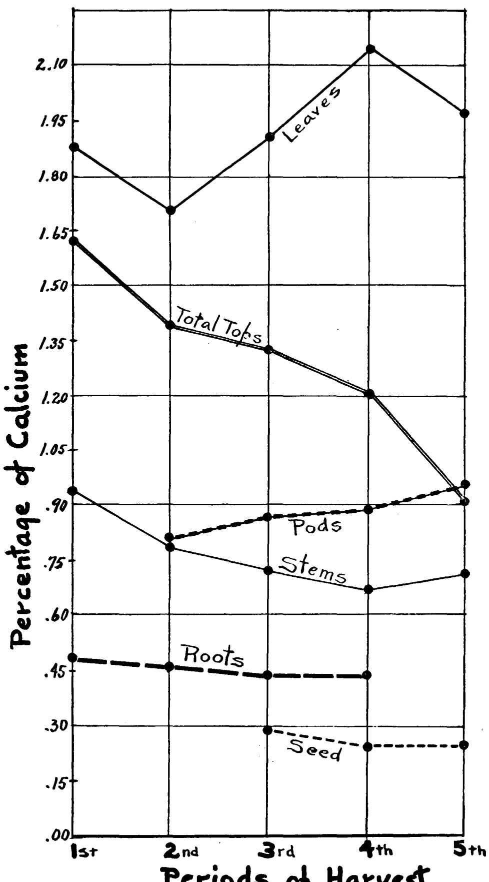

Fig. 8

The 6-year average trend of percentage of calcium in the total tops is downward with the approach of maturity.

The leaves contained a higher percentage of calcium than the other plant parts for all harvesting dates. There is no apparent consistent variation in percentage between dates. The 6-year average showed a higher percentage of calcium in the leaves on the fourth and fifth harvesting dates than on the other three.

The stems did not follow the leaves in percentage of calcium on the different dates, differing mainly in that the stems continued to decrease in percentage for a cutting date or two after the leaves had begun to increase. With two exceptions, the stems increased in percentage of calcium from the fourth to the fifth cutting.

The pods showed an increase in percentage of calcium as the plants matured, with the exceptions of the fourth date in 1924 and the third dates in 1926 and 1927. The 6-year average showed a marked increase in percentage with the development of the pods and maturity of the plant.

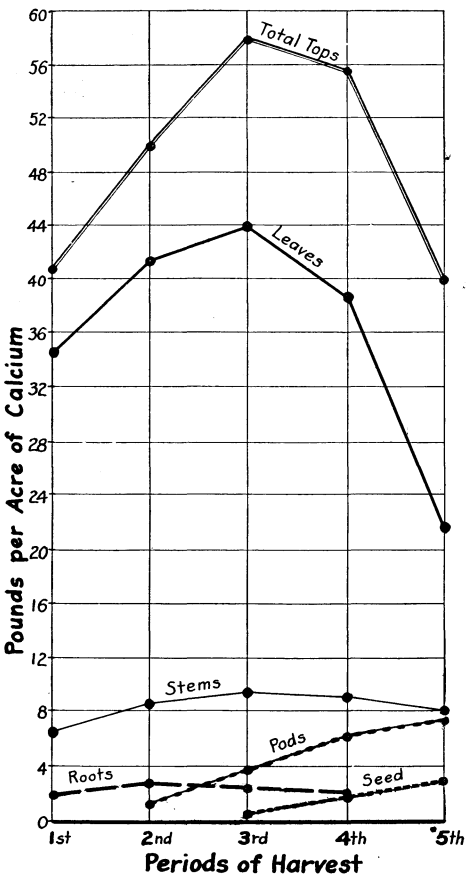

Fig. 9

The seeds were low in percentage of calcium, with some indications that immature seed was a little higher in calcium than mature seed.

The percentage of calcium in the plant parts was highest in the leaves, followed in order by pods, stems, roots, and seeds. The percentage of calcium in the roots remained fairly constant throughout the season, with some slight evidence of a higher percentage at the full-bloom stage of the plant than at other dates. The evidence for the end of the season is inconclusive, due to the loss of the sample for analysis for the last date in 1923.

Calcium per acre.—The pounds of calcium per acre in the several plant parts for the different dates of harvest and the movement of calcium in the plant were in marked contrast to nitrogen, phosphorus, and potassium, for which the relative amounts stored in the seeds were considerably higher.

The pounds of calcium per acre in the total tops increased rapidly until the leaves began to fall. The loss between the fourth and fifth cutting dates for all seasons, as well as the drop in 1925 and 1927 between the third and fourth cuttings, was largely due to the loss of leaves.

The plants contained, per acre, more calcium than other mineral elements, and this was found largely in the leaves. The pounds per acre of calcium in the leaves for the several cutting dates follow closely the curve for total calcium in the plant. There is some evidence that calcium was stored in the stems and then moved into the pods, where there was considerable accumulation towards the end of the season.

On the last date of harvest, the stems contained less calcium per acre than they did 2 weeks before, in spite of the higher percentage on the last date. This may be accounted for by the fact that the stems on the last date had lost 13 per cent in dry weight over the previous period, due largely to translocation of stored materials to other parts of the plant.

As the storage of calcium in the pods increased rapidly with their development, the amount in the stems decreased. Comparatively little of the total calcium in the plant was found in the seeds. The increase in calcium per acre in the seeds was due largely to the increase in weight of seeds, and not to the increase in percentage of calcium.

The increased storage of calcium in the pods seems to be more than sufficient to meet the needs of the seed, in contrast to the storage of surplus phosphorus in the pods, which is later reduced in amount as it moves into the seeds.

The storage of calcium in the roots, on the average, was fairly constant, with a slight increase about the time of pod and seed formation, after which there was a decrease to the end of the season. In 1926, this decrease did not come until the end of the season, between the fourth and fifth cuttings.

The amounts of calcium contained in the tops for the several dates of harvest, in terms of calcium oxide and calcium carbonate, are as follows:

	CALCIUM (CaO) Lb.	CALCIUM CARBONATE ($CaCO_3$) Lb.
August 1	57.2	102
August 15	72.2	129
September 1	81.1	145
September 15	78.1	139
October 1	55.7	99

MAGNESIUM

Table 10 and Figures 10 and 11 give the percentage and pounds per acre of magnesium in the crop.

Percentage of magnesium.—The percentage of magnesium in the total tops for the several dates of harvest followed, in a general way, the trend of calcium. The 6-year-average trends for the two elements are quite similar, there being a gradual decrease in percentage of magnesium from the first to the last dates of harvest. This trend is general for individual years, 1923 and 1925 showing some irregularities.

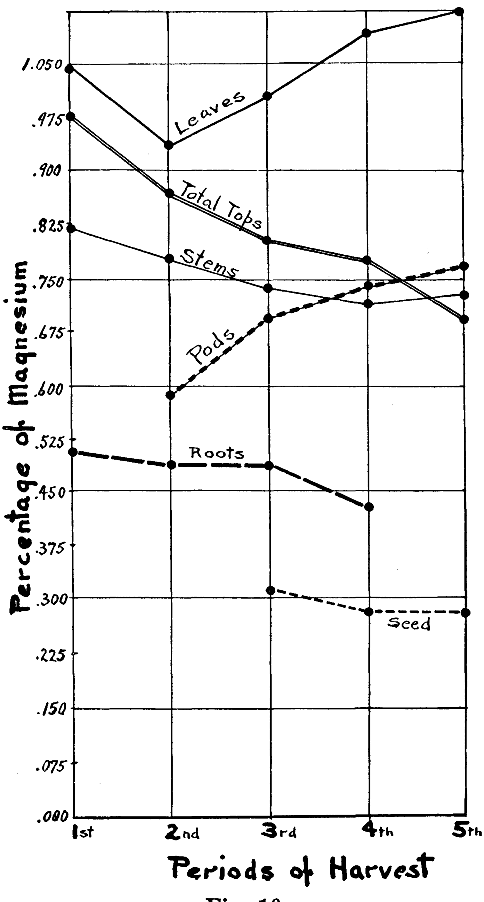

Fig. 10

The 6-year average percentage of magnesium in the leaves followed closely the trend of calcium with minor variations in individual years, the average tendency being for the percentage to increase from the beginning of seed formation to maturity.

The 6-year-average percentage of magnesium in the stems shows a slight tendency to decrease with maturity, and that in the pods showed an increase as the plants approached maturity. This increase was noted for 1922 and 1923, with slight variations for 1925, 1926, and 1927. In 1924, there was a drop from the third to the fourth date of harvest, followed by a very slight increase on the late date.

The percentage of magnesium in the seeds is low compared with other plant parts, with little evidence of change in percentage as the seeds ripen.

The percentage of magnesium in the roots had a slight downward trend from the first to the last dates of harvest.

Magnesium per acre.—The pounds per acre of magnesium in the total tops and in the several plant parts on the several dates of harvest followed closely the distribution of calcium.

For the 6-year average, the maximum amount of magnesium per acre was obtained on the third and fourth harvesting dates, with the third harvest a little ahead of the fourth. The loss in magnesium for the fifth harvest was due largely to the loss of leaves which had accumulated a large share of the magnesium found in the plant. This tendency for the third and fourth dates of harvest to yield maximum amounts of magnesium per acre is also characteristic of the individual years, with the exception of 1925, when it came on the second date.

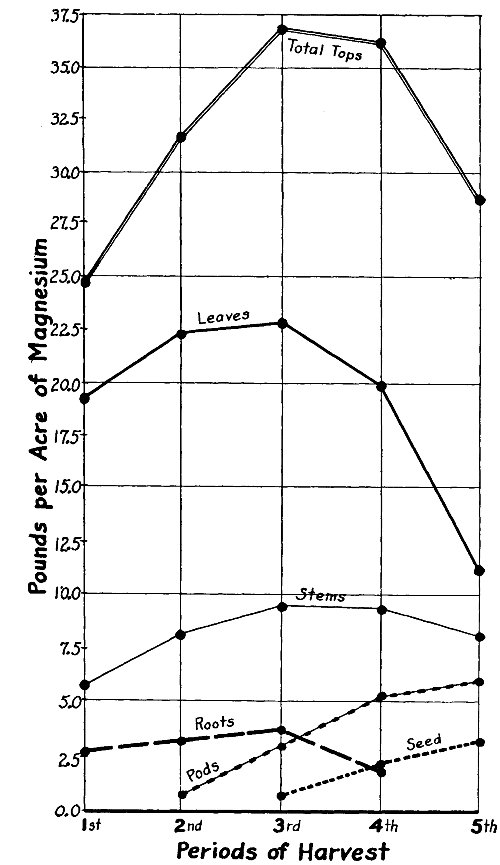

Fig. 11

The distribution of magnesium per acre in the leaves followed the same order as that in the total crop, largely because the leaves contained a higher percentage of magnesium than the other plant parts, and, consequently, relatively large amounts per acre. The loss of leaves upon the approach of maturity resulted in the loss of large amounts of magnesium. The translocation of magnesium from the leaves to the other plant parts is difficult to follow because of the loss through leaf fall. The stems, however, afford evidence of such a movement. For the 6-year average, the maximum amount of magnesium per acre in the stems was found on the third date of harvest, followed by a decrease toward the end of the season. The tendency to reach a maximum and then decrease with seed development is also noted for each of the 6 years of the test.

The pods showed a marked accumulation of magnesium towards the end of the season, the last harvest in 1925 and in 1926 showed only a slight loss over the fourth harvest. The general tendency for magnesium to accumulate in the pods is also evidenced by the increase in percentage as the plants matured.

The amount of magnesium per acre in the seeds is relatively small compared to that in the other plant parts.

The amount of magnesium found in the roots throughout the period under observation showed a tendency to decrease with maturity, following in a general way the percentage curve.

The amounts of magnesium contained in the tops for the several dates of harvest, in terms of magnesium oxide and magnesium carbonate, are as follows:

	MAGNESIUM OXIDE (MgO) Lb.	MAGNESIUM CARBONATE ($MgCO_3$) Lb.
August 1	40.9	103
August 15	52.4	132
September 1	59.8	150
September 15	60.3	152
October 1	47.2	119

THE REMOVAL FROM AND RETURN TO THE SOIL OF NITROGEN AND MINERAL MATTER

The removal of nitrogen, phosphoric acid, potash, calcium carbonate, and magnesium carbonate by the soybean crop when harvested at different stages of maturity for hay or seed and the return of these materials to the land by the crop residues in different methods of harvest is of interest from the standpoint of soil fertility.

Table 3 shows such removals and returns in the 6-year, Wooster experiment. The amounts are given in pounds per acre in round numbers. Extreme accuracy is not possible in determining the return to the soil for the last two stages of harvest—pods filled, seeds green, and seeds ripe, leaves falling—because the weight and composition of the dropped leaves were not determined *per se* but only by the difference in weight of harvested leaves between dates with some allowance for loss through translocation of material to the other plant parts. It is obvious that an apparent loss in weight of leaves could be due to such translocation, to loss of material from the plant through leaching, and to the actual loss of leaves.

TABLE 3.—Pounds per Acre of Nitrogen, Phosphoric Acid, Potash, Calcium Carbonate, and Magnesium Carbonate Estimated as Removed by the Crop or Returned to the Soil When Harvested as Follows, Based on the 6-year Average—Wooster Results:

	Nitrogen	Phosphoric acid	Potash	Calcium carbonate	Magnesium carbonate
	Lb	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Cut for hay, blooming stage					
Yield, 2537 pounds					
Removed in crop	69	16	28	102	103
Returned in roots and stubble	7	2	2	5	8
Cut for hay, pod-forming stage					
Yield, 3665 pounds					
Removed in crop	91	22	34	129	132
Returned in roots and stubble	9	3	3	6	10
Cut for hay, small-seed-forming stage					
Yield, 4349 pounds					
Removed in crop	113	27	38	145	150
Returned in roots and stubble	9	3	3	6	10
Cut for hay, pods filled, seeds green					
Yield, 4522 pounds					
Removed in crop	118	30	39	139	152
Returned in roots and stubble	7	2	2	5	8
Returned in fallen leaves	6	1	1	14	14
Cut for seed, seeds ripe, leaves falling					
Yield of seed, 1145 pounds					
Yield of leaves, stems, and pods, 2885 pounds					
Removed in seeds	72	20	24	7	14
Removed in leaves	20	5	6	50	45
Removed in stems and pods	20	5	11	40	62
Returned in roots and stubble	5	2	2	3	5
Returned in fallen leaves to date	16	4	3	37	37
Returned in leaves (if all fallen)	36	10	9	87	82

In the absence of information regarding the actual weight and composition of the dropped leaves, an attempt was made to estimate these as follows:

ESTIMATING THE LOSS OF DROPPED LEAVES FROM THE THIRD HARVEST (SMALL-SEED-FORMING STAGE) TO THE FOURTH HARVEST (PODS FILLED, SEEDS IN GREEN STAGE)

The 6-year average weight of leaves for the third harvest was 2347 pounds and 1812 pounds for the fourth harvest, an apparent loss of 535 pounds, part of which may have been due to translocation. However, during the seasons of 1922, 1923, 1924, and 1926, no appreciable loss of leaves took place by dropping but the loss in weight amounted to about 12 per cent. Taking 12 per cent from the 6-year average weight (2347 pounds) of leaves on the third date of harvest gives a calculated yield of 2065 pounds for the fourth date, which is 253 pounds more than the actual yield of 1812 pounds. The 253 pounds may represent the actual weight of dropped leaves. Another way of calculating the loss is to take the difference in the weights of hay harvested for the third and fourth dates, which shows a gain of 173 pounds per acre. During this period, there was an apparent loss in weight of the leaves of 535 pounds. If 173 pounds of this 535 pounds represent translocated material from the leaves, the difference, 362 pounds, would probably represent the actual loss through shattering. A rough figure of 300 pounds is therefore assumed to be the actual loss in leaves through dropping from the third to the fourth dates of harvest.

ESTIMATING THE LOSS OF DROPPED LEAVES FROM THE FOURTH HARVEST (PODS FILLED, SEEDS IN GREEN STAGE) TO THE FIFTH HARVEST (SEEDS RIPE, LEAVES FALLING)

The difference in the total weight of crop shows a loss of 492 pounds from the fourth to the fifth dates of harvest. Since photosynthesis had very materially slowed up, if not entirely ceased, by the fourth date, the loss may represent the actual loss of leaves. The apparent loss was 787 pounds, part of which may have been due to translocation. The weight of stems, pods, and seeds for the fourth date was 2710 pounds and on the fifth date 3005 pounds, or a gain of 295 pounds. If this gain is taken from the apparent loss of leaves, the remainder is 492 pounds, a figure exactly the same as obtained by the previous method of calculation. A loss of 500 pounds is assumed to represent roughly the loss of leaves from the fourth to the fifth dates of harvest.

The chemical composition of the dropped leaves is assumed to be approximately that of the harvested leaves during the period of dropping. Bearing these limitations in mind, one may draw the following conclusions from the table:

Nitrogen.—When harvested for hay at any one of the first four dates, the removal of nitrogen in the crop ranged from 69 to 118 pounds per acre. The return in the roots, stubble, and dropped leaves of from 7 to 12 pounds of nitrogen per acre to the soil was insignificant compared with this removal.

The removal and return when harvested for seed may be discussed as influenced by the following methods of harvest:

A. Cutting the crop and removing it from the land at the fifth stage of harvest, no straw being returned.

B. Delaying the harvest until all the leaves have fallen and threshing without the return of straw.

C. Harvesting the seed with a combine or threshing and returning the straw to the land.

With Method A, 112 pounds of nitrogen per acre would have been removed in the seeds, pods, leaves, and stems and 21 pounds returned to the soil in roots, stubble, and dropped leaves. With Method B, the seeds, stems, and pods would have removed 92 pounds of nitrogen and the roots, stubble, and dropped leaves returned 41 pounds. With Method C, the seeds would have removed 72 pounds of nitrogen and returned 60 pounds in straw, dropped leaves, roots, and stubble.

Phosphoric acid.—Relatively small amounts of phosphoric acid equivalent were returned to the soil in the roots and stubble when the crop was cut for hay. The removal in the hay crops ranged from 16 to 30 pounds, according to the stage of development, 27 to 30 pounds at the time soybeans should be cut for hay. More than one-half of the total phosphorus in the crop is contained in the seed. If harvested for seed by Method A, 30 pounds of phosphoric equivalent would be removed and 5 pounds returned to the land; by Method B, 25 pounds removed and 10 pounds returned; and by Method C, 20 pounds removed and 15 returned to the land.

Potash.—The removal of potash equivalent in the hay crop was one-third to one-half more than that of phosphoric acid equivalent. Relatively small amounts were returned to the land in roots and stubble.

The seeds are rich in potassium, the stems and pods containing about one-half and the leaves one-third as much. If harvested for seed by Method A, 41 pounds of potash would be removed and 6 pounds returned to the soil; by Method B, 35 pounds would be removed and 12 pounds returned; and by Method C, 24 pounds removed and 23 pounds returned to the soil.

Calcium carbonate and magnesium carbonate.—The mineral matter in the soybean plant is made up largely of calcium and magnesium salts. Expressed as carbonate, then, the two elements are found in about equal amounts in the plant, mostly in the leaves. The seeds are relatively poor in calcium and magnesium, in contrast to their content of phosphorus and potassium. Approximately 200 to 300 pounds of calcium and magnesium carbonate equivalent were removed in the hay crops from the first to the fourth stages of harvest.

When harvested as a seed crop by Method A, 97 pounds of calcium carbonate and 121 pounds of magnesium carbonate were removed and 40 pounds of calcium carbonate and 42 pounds of magnesium carbonate returned to the land. By Method B, the removal would have amounted to 47 pounds of calcium carbonate and 78 pounds of magnesium carbonate and the return to the land, 90 pounds of calcium carbonate and 87 pounds of magnesium carbonate; and by Method C, the removal would have been 7 pounds of calcium carbonate and 14 pounds of magnesium carbonate and the return, 130 pounds of calcium carbonate and 149 pounds of magnesium carbonate.

There is an apparent loss of 21 pounds of calcium carbonate and 11 pounds of magnesium carbonate from the fourth to the fifth dates of harvest not accounted for. This may have been lost through leaching of the leaves, which are rich in these minerals.

TABLE 4.—Yield per Acre of Soybeans Harvested at Different Dates—Wooster

Moisture content approximately 7 per cent

Date cut—1922					
	Aug. 1	Aug. 15	Aug. 31	Sept. 16	Oct. 1
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Leaves	2,821	3,319	3,673	2,772	2,006
Stems	1,116	1,803	2,386	1,932	1,907
Pods	....	....	....	604	670
Seeds	....	....	....	553	887
Total tops	3,937	5,122	6,059	5,861	5,470
Date cut—1923					
	Aug. 1	Aug. 15	Aug. 31	Sept. 16	Oct. 1
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Leaves	1,467	2,221	2,119	2,135	733
Stems	533	903	1,152	1,148	688
Pods	....	....	463	618	1,130
Seeds	....	....	195	619	1,367
Total tops	2,000	3,124	3,929	4,520	3,918
Roots	258	364	441	430	247
Date cut—1924					
	Aug. 6	Aug. 18	Aug. 28	Sept. 15	Oct. 1
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Leaves	1,884	2,576	3,064	2,912	2,401
Stems	559	971	1,303	1,636	1,334
Pods	....	....	424	953	911
Seeds	....	....	....	421	1,250
Total tops	2,443	3,547	4,791	5,922	5,896
Date cut—1925					
	Aug. 3	Aug. 14	Sept. 1	Sept. 16	Oct. 2
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Leaves	1,937	2,741	1,447	611	394
Stems	1,035	1,253	1,067	913	957
Pods	....	388	435	501	436
Seeds	....	....	669	978	935
Total tops	2,972	4,382	3,618	3,003	2,722
Roots	404	574	421	258	221

TABLE 4.—**Yield per Acre of Soybeans Harvested at Different Dates—Wooster.—Continued**

Moisture content approximately 7 per cent

	Date cut—1926				
	Aug. 4	Aug. 18	Sept. 3	Sept. 15	Oct. 4
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Leaves	1,556	1,762	1,761	1,497	283
Stems	692	985	1,032	1,036	784
Pods	....	267	747	851	816
Seeds	....	....	555	1,186	1,373
Total tops	2,248	3,014	4,095	4,570	3,256
Roots	383	452	489	578	369
	Date cut—1927				
	Aug. 9	Aug. 22	Sept. 2	Sept. 19	Oct. 3
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Leaves	1,184	1,830	2,020	946	334
Stems	443	779	935	809	816
Pods	....	196	655	700	713
Seeds	....	....	....	807	1,062
Total tops	1,627	2,805	3,610	3,262	2,925
Roots	518	772	848	552	465
	6-year average				
	1st harvest	2d harvest	3d harvest	4th harvest	5th harvest
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Leaves	1,808	2,408	2,347	1,812	1,025
Stems	729	1,115	1,312	1,245	1,081
Pods	....	142	454	704	779
Seeds	....	....	236	761	1,145
Total tops	2,537	3,665	4,349	4,522	4,030
	4-year average—tops and roots				
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Total tops	2,212	3,331	3,813	3,839	3,205
Roots	391	540	550	454	325
Ratio roots to tops	1:5.7	1:6.2	1:6.9	1:8.4	1:9.9

TABLE 5.—Protein

Percentage and pounds per acre

Date cut—1922	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	19.9	561	18.5	614	18.9	694	14.1	391	11.8	237
Stems	9.4	105	9.5	171	11.9	283	8.6	165	6.3	120
Pods	....	....	....	....	....	....	15.0	91	10.0	67
Seeds	....	....	....	....	....	....	41.9	232	40.9	363
Total tops	16.9	666	15.3	785	16.1	977	15.0	879	14.4	787

Date cut—1923	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	17.2	252	14.2	316	11.1	234	8.9	191	8.2	60
Stems	9.0	48	6.7	61	5.0	57	3.4	39	2.7	18
Pods	....	....	....	....	10.3	48	4.6	28	3.7	42
Seeds	....	....	....	....	40.2	78	33.5	208	31.9	436
Total tops	15.0	300	12.3	377	10.7	417	10.3	466	14.3	556

Date cut—1924	Aug. 6		Aug. 18		Aug. 28		Sept. 15		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	17.8	336	20.0	515	20.1	615	17.4	507	12.7	305
Stems	11.4	64	13.4	130	12.9	168	11.4	186	6.9	92
Pods	....	....	....	....	22.3	95	18.3	174	10.4	95
Seeds	....	....	....	....	....	....	39.1	165	38.1	477
Total tops	16.3	400	18.2	645	18.3	878	17.4	1032	16.4	969

Date cut—1925	Aug. 3		Aug. 14		Sept. 1		Sept. 16		Oct. 2	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	19.9	386	16.9	464	12.6	182	10.8	66	17.3	68
Stems	8.3	86	8.7	109	9.1	97	6.1	56	6.1	59
Pods	....	....	25.4	99	13.2	57	7.4	37	9.1	40
Seeds	....	....	....	....	63.5	425	43.9	429	44.9	420
Total tops	15.9	472	15.3	672	21.1	761	19.6	588	21.6	587

TABLE 5.—Protein.—Continued

Percentage and pounds per acre

	Date cut—1926									
	Aug. 4		Aug. 18		Sept. 3		Sept. 15		Oct. 4	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	24.7	385	20.4	359	16.6	292	13.9	209	12.2	35
Stems	13.2	91	12.6	124	11.8	109	7.0	73	6.9	54
Pods	....	....	23.6	63	17.1	128	12.4	106	11.7	96
Seeds	....	....	....	....	36.8	204	44.3	525	45.1	620
Total tops	21.2	476	18.1	546	17.9	733	19.9	913	24.7	805
	Date cut—1927									
	Aug. 9		Aug. 22		Sept. 2		Sept. 19		Oct. 4	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	19.2	227	15.6	285	13.8	278	10.8	102	10.0	33
Stems	9.5	42	7.7	60	6.5	61	4.5	37	3.8	31
Pods	....	....	17.8	35	21.3	139	6.2	43	5.7	40
Seeds	....	....	....	....	....	....	47.6	384	37.3	396
Total tops	16.6	269	13.6	380	13.2	478	17.4	566	17.1	500
	6-year average									
	1st harvest		2d harvest		3d harvest		4th harvest		5th harvest	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	19.8	359	17.6	425	15.5	383	12.6	244	12.0	124
Stems	10.1	73	9.7	109	9.5	129	6.8	92	5.4	62
Pods	....	....	22.3*	33	16.8†	78	10.6	80	8.4	63
Seeds	....	....	....	....	46.8*	118	41.7	324	39.7	452
Total tops	17.0	432	15.5	567	16.2	708	16.6	740	18.1	701

*3 years only.
†5 years only.

TABLE 6.—Nitrogen

Percentage and pounds per acre

	Date cut—1922									
	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	3.18	90.0	2.96	98.0	3.02	111.0	2.26	63.0	1.89	38.0
Stems	1.51	17.0	1.52	27.0	1.90	45.0	1.37	26.0	1.01	19.0
Pods	....	....	....	....	....	....	2.41	14.0	1.61	11.0
Seeds	....	....	....	....	....	....	6.70	37.0	6.55	58.0
Total tops	2.71	107.0	2.45	125.0	2.58	156.0	2.40	140.0	2.31	126.0
	Date cut—1923									
	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	2.75	40.6	2.28	50.6	1.77	37.5	1.40	30.0	1.32	9.7
Stems	1.43	7.6	1.06	9.6	0.80	9.2	0.54	6.2	0.42	2.9
Pods	....	....	....	....	1.63	7.5	0.72	4.4	0.59	6.6
Seeds	....	....	....	....	6.30	12.3	5.27	32.6	5.02	68.6
Total tops	2.41	48.2	1.93	60.2	1.69	66.5	1.62	73.2	2.18	87.8
Roots	1.20	3.1	1.08	3.9	0.92	4.1	0.84	3.6	0.78	1.9
	Date cut—1924									
	Aug. 6		Aug. 18		Aug. 28		Sept. 15		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	2.85	53.7	3.20	82.4	3.21	98.3	2.79	81.2	2.03	48.7
Stems	1.82	10.2	2.14	20.8	2.07	27.0	1.82	29.8	1.10	14.7
Pods	....	....	....	....	3.57	15.1	2.93	27.9	1.67	15.2
Seeds	....	....	....	....	....	....	6.26	26.3	6.10	76.2
Total tops	2.62	63.9	2.91	103.2	2.93	140.4	2.79	165.2	2.62	154.8
	Date cut—1925									
	Aug. 3		Aug. 14		Sept. 1		Sept. 16		Oct. 2	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	3.19	61.8	2.71	74.2	2.02	29.2	1.74	10.6	2.77	10.9
Stems	1.32	13.7	1.39	17.4	1.46	15.5	0.98	8.9	0.98	9.4
Pods	....	....	4.07	15.8	2.11	9.2	1.18	5.9	1.46	6.3
Seeds	....	....	....	....	10.16	68.0	7.02	68.7	7.19	67.2
Total tops	2.54	75.5	2.45	107.4	3.37	121.9	3.13	94.1	3.44	93.8
Roots	1.53	6.2	1.90	10.9	1.62	6.8	1.88	4.8	1.59	3.5

TABLE 6.—Nitrogen.—Continued

Percentage and pounds per acre

	Date cut—1926									
	Aug. 4		Aug. 18		Sept. 3		Sept. 15		Oct. 4	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	3.96	61.6	3.26	57.5	2.65	46.7	2.23	33.4	1.95	5.5
Stems	2.11	14.6	2.02	19.8	1.89	19.5	1.13	11.7	1.11	8.7
Pods	....	....	3.78	10.1	2.74	20.4	1.99	16.9	1.88	15.3
Seeds	....	....	....	....	5.88	32.6	7.08	84.0	7.22	99.1
Total tops	3.39	76.2	2.90	87.4	2.91	119.2	3.19	146.0	3.95	128.6
Roots	2.09	8.0	1.92	8.7	1.68	8.2	1.67	9.6	1.39	5.1

	Date cut—1927									
	Aug. 9		Aug. 22		Sept. 2		Sept. 19		Oct. 3	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	3.07	36.3	2.49	45.6	2.20	44.5	1.73	16.3	1.60	5.3
Stems	1.53	6.7	1.23	9.6	1.04	9.7	0.73	5.9	0.60	4.9
Pods	....	....	2.84	5.6	3.40	22.3	0.99	6.9	0.91	6.5
Seeds	....	....	....	....	....	....	7.61	61.4	5.96	63.3
Total tops	2.64	43.0	2.17	60.8	2.12	76.5	2.77	90.5	2.73	80.0
Roots	2.02	10.4	1.81	13.9	1.95	16.5	1.78	9.8	1.95	9.0

	6-year average									
	1st harvest		2d harvest		3d harvest		4th harvest		5th harvest	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	3.17	57.3	2.83	68.1	2.48	61.2	2.01	39.1	1.92	19.7
Stems	1.59	11.6	1.56	17.4	1.52	20.9	1.09	14.7	0.86	9.9
Pods	....	....	3.56	5.2	2.69	12.4	1.69	12.6	1.34	10.1
Seeds	....	....	....	....	7.49	18.8	6.67	51.6	6.35	72.1
Total tops	2.72	68.9	2.47	90.6	2.59	113.3	2.66	118.0	2.89	111.8
Roots (4 yr.)	1.71	6.9	1.68	9.4	1.54	8.9	1.54	7.0	1.43	4.9

TABLE 7.—Phosphorus

Percentage and pounds per acre

	Date cut—1922									
	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.31	8.7	0.29	9.8	0.27	10.1	0.21	5.7	0.17	3.5
Stems	0.26	2.9	0.19	3.5	0.18	4.4	0.13	2.4	0.08	1.5
Pods	....	....	....	....	....	....	0.21	1.3	0.13	0.9
Seeds	....	....	....	....	....	....	0.64	3.5	0.62	5.5
Total tops	0.29	11.6	0.26	13.3	0.24	14.5	0.22	12.9	0.21	11.4
	Date cut—1923									
	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.23	3.3	0.25	5.5	0.25	5.4	0.14	2.9	0.18	1.3
Stems	0.21	1.1	0.19	1.8	0.13	1.5	0.12	1.4	0.07	0.5
Pods	....	....	....	....	0.29	1.3	0.23	1.4	0.12	1.3
Seeds	....	....	....	....	0.81	1.6	0.75	4.7	0.88	12.0
Total tops	0.22	4.4	0.23	7.3	0.25	9.8	0.23	10.4	0.39	15.1
Roots	0.16	0.4	0.19	0.7	0.18	0.8	0.15	0.6	....	....
	Date cut—1924									
	Aug. 6		Aug. 18		Aug. 28		Sept. 15		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.33	6.2	0.33	8.6	0.33	10.1	0.27	7.8	0.22	5.2
Stems	0.32	1.8	0.33	3.2	0.31	4.1	0.23	3.8	0.13	1.8
Pods	....	....	....	....	0.51	2.1	0.38	3.7	0.20	1.8
Seeds	....	....	....	....	....	....	0.86	3.6	0.80	9.9
Total tops	0.32	8.0	0.33	11.8	0.34	16.3	0.32	18.9	0.32	18.7
	Date cut—1925									
	Aug. 3		Aug. 14		Sept. 1		Sept. 16		Oct. 2	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.29	5.6	0.26	7.1	0.21	3.1	0.19	1.1	0.27	1.1
Stems	0.21	2.2	0.19	2.3	0.14	1.4	0.09	0.8	0.10	0.9
Pods	....	....	0.54	2.1	0.19	0.8	0.12	0.6	0.15	0.7
Seeds	....	....	....	....	0.77	5.2	0.80	7.8	0.72	6.7
Total tops	0.26	7.8	0.26	11.6	0.29	10.5	0.35	10.4	0.34	9.4
Roots	0.20	0.8	0.23	1.3	0.21	0.9	0.20	0.5	0.18	0.4

TABLE 7.—Phosphorus.—Continued

Percentage and pounds per acre

Date cut—1926

	Aug. 4		Aug. 18		Sept. 3		Sept. 15		Oct. 4	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.30	4.6	0.29	5.1	0.22	3.9	0.22	3.4	0.22	0.6
Stems	0.24	1.7	0.20	2.0	0.17	1.8	0.11	1.1	0.11	0.8
Pods	....	....	0.48	1.3	0.25	1.9	0.20	1.7	0.18	1.5
Seeds	....	....	....	....	0.76	4.2	0.77	9.1	0.82	11.2
Total tops	0.28	6.3	0.28	8.3	0.29	11.7	0.33	15.3	0.44	14.2
Roots	0.22	0.8	0.17	0.8	0.17	0.8	0.17	1.0	0.17	0.6

Date cut—1927

	Aug. 9		Aug. 22		Sept. 2		Sept. 19		Oct. 3	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.29	3.5	0.23	4.2	0.21	4.2	0.17	1.6	0.16	0.5
Stems	0.23	1.0	0.20	1.5	0.16	1.5	0.11	0.9	0.09	0.7
Pods	....	....	0.36	0.7	0.41	2.7	0.13	0.9	0.12	0.9
Seeds	....	....	....	....	....	....	0.74	5.9	0.69	7.4
Total tops	0.28	4.5	0.23	6.5	0.23	8.4	0.29	9.4	0.32	9.5
Roots	0.24	1.2	0.22	1.7	0.24	2.0	0.24	1.3	0.20	0.9

6-year average

	1st harvest		2d harvest		3d harvest		4th harvest		5th harvest	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.29	5.3	0.28	6.7	0.25	6.1	0.20	3.7	0.20	2.0
Stems	0.24	1.8	0.22	2.4	0.18	2.4	0.13	1.7	0.10	1.0
Pods	....	....	0.46*	0.7	0.33†	1.5	0.21	1.6	0.15	1.2
Seeds	....	....	....	....	0.78*	1.8	0.76	5.8	0.75	8.8
Total tops	0.28	7.1	0.26	9.8	0.27	11.8	0.29	12.9	0.34	13.0
Roots (4 yr.)	0.20	0.8	0.20	1.1	0.20	1.1	0.19	0.9	....	....

*3 years only.
†5 years only.

TABLE 8.—Potassium

Percentage and pounds per acre

	Date cut—1922									
	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.00	28.3	0.96	31.9	0.86	31.6	0.61	16.9	0.65	13.0
Stems	0.92	10.3	0.54	9.7	0.49	11.7	0.30	5.8	0.27	5.1
Pods	....	....	....	....	....	....	0.78	4.7	0.88	5.9
Seeds	....	....	....	....	....	....	1.84	10.2	1.58	14.0
Total tops	0.98	38.6	0.81	41.6	0.71	43.3	0.64	37.6	0.69	38.0
	Date cut—1923									
	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.15	16.9	1.01	22.5	0.80	17.0	0.50	10.6	0.71	5.2
Stems	0.79	4.2	0.67	6.1	0.45	5.2	0.39	4.4	0.26	1.8
Pods	....	....	....	....	1.53	7.1	1.06	6.6	1.10	12.4
Seeds	....	....	....	....	2.31	4.5	2.17	13.4	2.09	28.6
Total tops	1.05	21.1	0.91	28.6	0.86	33.8	0.77	35.0	1.22	48.0
Roots	0.45	1.2	0.34	1.2	0.31	1.4	0.27	1.1	....	....
	Date cut—1924									
	Aug. 6		Aug. 18		Aug. 28		Sept. 15		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.73	13.8	0.74	19.1	0.64	19.5	0.45	13.1	0.35	8.4
Stems	0.87	4.9	0.78	7.5	0.52	6.7	0.34	5.6	0.19	2.6
Pods	....	....	....	....	1.49	6.3	1.02	9.7	0.73	6.6
Seeds	....	....	....	....	....	....	1.88	7.9	1.79	22.4
Total tops	0.76	18.7	0.75	26.7	0.68	32.6	0.61	36.3	0.68	40.0
	Date cut—1925									
	Aug. 3		Aug. 14		Sept. 1		Sept. 16		Oct. 2	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.99	19.2	0.74	20.4	0.71	10.2	0.41	2.5	0.41	1.6
Stems	0.73	7.5	0.37	4.7	0.44	4.8	0.27	2.4	0.26	2.5
Pods	....	....	1.84	7.1	1.41	6.1	1.05	5.2	1.00	4.4
Seeds	....	....	....	....	1.32	8.8	1.74	17.1	1.53	14.3
Total tops	0.90	26.8	0.73	32.2	0.83	30.0	0.99	27.3	0.84	22.8
Roots	0.42	1.7	0.46	2.6	0.37	1.5	0.44	1.1	0.35	0.8

TABLE 8.—Potassium.—Continued

Percentage and pounds per acre

	Date cut—1926									
	Aug. 4		Aug. 18		Sept. 3		Sept. 15		Oct. 4	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.76	11.9	0.81	14.3	0.65	11.5	0.41	6.1	0.40	1.1
Stems	0.84	5.8	0.63	6.2	0.42	4.3	0.31	3.3	0.29	2.3
Pods	....	....	1.76	4.7	1.08	8.0	0.78	6.6	0.74	6.1
Seeds	....	....	....	....	0.88	4.9	1.69	20.0	1.54	21.2
Total tops	0.79	17.7	0.83	25.2	0.70	28.7	0.79	36.0	0.94	30.7
Roots	0.39	1.5	0.36	1.6	0.35	1.7	0.33	1.9	0.30	1.1
	Date cut—1927									
	Aug. 9		Aug. 22		Sept. 2		Sept. 19		Oct. 3	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.00	11.8	0.62	11.4	0.49	9.9	0.32	3.0	0.28	0.9
Stems	0.91	4.0	0.42	3.3	0.33	3.1	0.26	2.1	0.20	1.7
Pods	....	....	1.23	2.4	1.22	8.0	0.70	4.9	0.52	3.7
Seeds	....	....	....	....	....	....	1.54	12.5	1.68	17.8
Total tops	0.97	15.8	0.61	17.1	0.58	20.9	0.69	22.5	0.82	24.1
Roots	0.56	2.9	0.49	3.8	0.48	4.1	0.47	2.6	0.41	1.9
	6-year average									
	1st harvest		2d harvest		3d harvest		4th harvest		5th harvest	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.94	17.0	0.81	19.9	0.69	16.6	0.45	8.7	0.47	5.0
Stems	0.84	6.1	0.57	6.2	0.44	6.0	0.31	3.9	0.24	2.6
Pods	....	....	1.61*	2.4	1.35†	5.9	0.90	6.3	0.83	6.5
Seeds	....	....	....	....	1.50*	3.0	1.81	13.5	1.70	19.7
Total tops	0.91	23.1	0.77	28.5	0.73	31.6	0.75	32.4	0.86	33.9
Roots (4 yr.)	0.45	1.8	0.41	2.3	0.38	2.2	0.38	1.7	....	....

*3 years only.
†5 years only.

TABLE 9.—Calcium

Percentage and pounds per acre

Date cut—1922

	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.73	48.9	1.70	56.5	1.65	60.8	2.06	57.1	2.06	41.4
Stems	0.85	9.5	0.63	11.4	0.64	15.2	0.60	11.6	0.66	12.6
Pods	....	....	....	....	....	....	0.85	5.2	0.93	6.2
Seeds	....	....	....	....	....	....	0.28	1.5	0.25	2.2
Total tops	1.48	58.4	1.33	67.9	1.26	76.0	1.45	75.4	1.14	62.4

Date cut—1923

	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.50	22.2	1.45	32.1	2.10	44.4	2.06	44.0	1.51	11.1
Stems	0.74	4.0	0.70	6.3	0.49	5.6	0.50	5.8	0.63	4.3
Pods	....	....	....	....	1.00	4.6	1.09	6.7	1.20	13.5
Seeds	....	....	....	....	0.39	0.8	0.31	1.9	0.32	4.3
Total tops	1.31	26.2	1.23	38.4	1.41	55.4	1.29	58.4	0.85	33.2
Roots	0.47	1.2	0.52	1.9	0.47	2.1	0.45	2.0	....	....

Date cut—1924

	Aug. 6		Aug. 18		Aug. 28		Sept. 15		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	2.79	52.6	1.76	45.4	1.76	54.0	2.00	58.3	2.28	54.8
Stems	1.51	8.5	1.44	14.0	1.27	16.6	1.19	19.4	1.22	16.3
Pods	....	....	....	....	0.99	4.2	0.79	7.6	0.85	7.7
Seeds	....	....	....	....	....	....	0.23	1.0	0.18	2.3
Total tops	2.50	61.0	1.67	59.4	1.56	74.8	1.46	86.2	1.38	81.1

Date cut—1925

	Aug. 3		Aug. 14		Sept. 1		Sept. 16		Oct. 2	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.71	33.2	1.85	50.6	2.18	31.6	1.84	11.2	1.70	6.7
Stems	0.64	6.6	0.58	7.3	0.60	6.4	0.56	5.1	0.54	5.2
Pods	....	....	0.73	2.8	0.80	3.5	0.81	4.1	0.88	3.8
Seeds	....	....	....	....	0.25	1.6	0.23	2.3	0.27	2.5
Total tops	1.34	39.8	1.39	60.7	1.19	43.2	0.76	22.8	0.67	18.3
Roots	0.47	1.9	0.50	2.9	0.48	2.0	0.53	1.4	0.40	0.9

TABLE 9.—Calcium.—Continued

Percentage and pounds per acre

Date cut—1926

	Aug. 4		Aug. 18		Sept. 3		Sept. 15		Oct. 4	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.89	29.5	1.98	35.0	2.35	41.5	3.00	44.9	2.87	8.1
Stems	0.91	6.3	0.79	7.7	0.73	7.6	0.72	7.5	0.76	5.9
Pods	....	....	0.83	2.2	0.76	5.6	0.83	7.0	0.84	6.8
Seeds	....	....	....	....	0.23	1.3	0.24	2.8	0.26	3.6
Total tops	1.59	35.8	1.49	44.9	1.37	56.0	1.36	62.3	0.75	24.5
Roots	0.64	2.4	0.53	2.4	0.53	2.6	0.46	2.6	0.48	1.8

Date cut—1927

	Aug. 9		Aug. 22		Sept. 2		Sept. 19		Oct. 3	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.66	19.7	1.54	28.1	1.62	32.8	1.88	17.8	1.87	6.2
Stems	1.00	4.4	0.71	5.5	0.58	5.4	0.48	3.8	0.45	3.7
Pods	....	....	0.93	1.8	0.74	4.9	0.92	6.4	0.99	7.0
Seeds	....	....	....	....	....	....	0.23	1.9	0.21	2.2
Total tops	1.48	24.1	1.26	35.4	1.19	43.1	0.92	29.9	0.66	19.2
Roots	0.39	2.0	0.29	2.2	0.30	2.6	0.33	1.8	0.43	2.0

6-year average

	1st harvest		2d harvest		3d harvest		4th harvest		5th harvest	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.88	34.3	1.71	41.8	1.94	44.2	2.14	38.9	2.05	21.4
Stems	0.94	6.5	0.81	8.7	0.72	9.4	0.67	8.9	0.71	8.0
Pods	....	....	0.83*	1.1	0.86†	3.8	0.88	6.2	0.95	7.5
Seeds	....	....	....	....	0.29*	0.6	0.25	1.9	0.25	2.9
Total tops	1.62	40.9	1.39	51.6	1.33	58.0	1.21	55.8	0.91	39.8
Roots	0.49	1.9	0.46	2.4	0.44	2.3	0.44	1.9	....	....

*3 years only.
†5 years only.

TABLE 10.—Magnesium

Percentage and pounds per acre

Date cut—1922

	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.98	27.8	0.86	28.5	0.79	29.2	0.88	24.4	0.96	19.2
Stems	0.70	7.8	0.61	10.9	0.52	12.5	0.53	10.3	0.53	10.1
Pods	....	....	....	....	....	....	0.59	3.6	0.62	4.2
Seeds	....	....	....	....	....	....	0.28	1.6	0.29	2.6
Total tops	0.90	35.6	0.77	39.4	0.69	41.7	0.68	39.9	0.66	36.1

Date cut—1923

	Aug. 1		Aug. 15		Aug. 31		Sept. 16		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.17	17.3	1.14	25.4	1.35	28.6	1.47	31.5	1.13	8.3
Stems	0.81	4.3	0.74	6.7	0.65	7.5	0.67	7.6	0.77	5.3
Pods	....	....	....	....	0.83	3.9	0.98	6.1	0.03	11.6
Seeds	....	....	....	....	0.40	0.8	0.37	2.3	0.40	5.4
Total tops	1.08	21.6	1.03	32.1	1.04	40.8	1.05	47.5	0.92	30.6
Roots	0.48	1.2	0.65	2.3	0.57	2.5	0.53	2.3	....	....

Date cut—1924

	Aug. 6		Aug. 18		Aug. 28		Sept. 15		Oct. 1	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.49	28.1	1.02	26.3	0.93	28.5	1.04	30.4	1.15	27.7
Stems	1.21	6.8	1.31	12.7	1.31	17.0	1.38	22.6	1.37	18.2
Pods	....	....	....	....	0.59	2.5	0.51	4.9	0.53	4.8
Seeds	....	....	....	....	....	....	0.22	0.9	0.24	3.0
Total tops	1.43	34.9	1.10	39.1	1.00	48.0	0.99	58.8	0.91	53.7

Date cut—1925

	Aug. 3		Aug. 14		Sept. 1		Sept. 16		Oct. 2	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.89	17.3	0.92	25.1	1.09	15.8	0.88	5.4	0.96	3.8
Stems	0.62	6.4	0.62	7.8	0.65	7.0	0.50	4.6	0.52	5.0
Pods	....	....	0.58	2.2	0.83	3.6	0.81	4.0	0.83	3.6
Seeds	....	....	....	....	0.28	1.9	0.27	2.6	0.25	2.4
Total tops	0.80	23.7	0.80	35.2	0.62	28.3	0.55	16.6	0.54	14.7
Roots	0.53	2.1	0.46	2.6	0.49	2.0	0.39	1.0	0.29	0.6

TABLE 10.—Magnesium.—Continued

Percentage and pounds per acre

	Date cut—1926									
	Aug. 4		Aug. 18		Sept. 3		Sept. 15		Oct. 4	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.89	13.9	0.83	14.7	0.99	17.5	1.16	17.4	1.30	3.7
Stems	0.71	4.9	0.65	6.4	0.63	6.5	0.62	6.4	0.59	4.6
Pods	....	....	0.51	1.4	0.57	4.3	0.65	5.5	0.62	5.1
Seeds	....	....	....	....	0.26	1.4	0.25	3.0	0.28	3.9
Total tops	0.83	18.8	0.74	22.5	0.73	29.7	0.71	32.3	0.53	17.3
Roots	0.51	2.0	0.43	1.9	0.50	2.4	0.43	2.5	0.33	1.2
	Date cut—1926									
	Aug. 9		Aug. 22		Sept. 2		Sept. 19		Oct. 3	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	0.83	9.8	0.80	14.6	0.87	17.5	1.10	10.4	1.29	4.3
Stems	0.86	3.8	0.73	5.7	0.68	6.3	0.61	5.0	0.61	5.0
Pods	....	....	0.69	1.4	0.61	4.0	0.88	6.1	0.97	6.9
Seeds	....	....	....	....	....	....	0.27	2.2	0.25	2.7
Total tops	0.84	13.7	0.77	21.7	0.77	27.8	0.72	23.6	0.64	18.9
Roots	0.52	2.7	0.43	3.3	0.42	3.6	0.37	2.0	0.33	1.5
	6-year average									
	1st harvest		2d harvest		3d harvest		4th harvest		5th harvest	
	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.	Pct.	Lb.
Leaves	1.04	19.0	0.93	22.4	1.00	22.9	1.09	19.9	1.13	11.1
Stems	0.82	5.7	0.78	8.4	0.74	9.5	0.72	9.4	0.73	8.0
Pods	....	....	0.59*	0.8	0.69†	3.0	0.74	5.0	0.77	6.0
Seeds	....	....	....	....	0.31*	0.7	0.28	2.1	0.28	3.3
Total tops	0.98	24.7	0.87	31.6	0.81	36.1	0.78	36.4	0.70	28.5
Roots	0.51	2.0	0.49	2.6	0.49	2.6	0.43	2.0	....	....

*3 years only.
†5 years only.

GENERAL SUMMARY

Rate and date of planting soybeans.—Five years' work on rates and dates of planting Manchu and Peking soybeans are reported. The experiments were conducted on Miami silt loam and Miami, Brookston, and Clyde silty clay loams at Columbus.

Three rates of planting were used: thick, plants ¾ to one inch apart; medium, plants 3½ inches apart; and thin, plants 8 inches apart. The rows were 28 inches apart.

First planting dates ranged from April 10 to 19. Each year subsequent plantings were made May first and continued at intervals of 2 weeks until August first.

All yield determinations were made from "rod-rows" usually in four replications.

The rate of planting affected the height and habit of growth of both varieties; the thicker the planting, the taller and more slender the plants.

The rate of planting did not influence the proportion of stems to leaves.

The rate of planting apparently did not affect the nitrogen content of the plants.

The rate of planting had no effect on the percentage of fiber in the plants.

The thick rate of planting produced the highest yields of forage on all dates of planting.

The thick rate of planting produced the highest yields of seed on all dates. If the net yield of seed is considered the advantage of the thick rate over the medium is slight or lacking.

The best dates of planting Manchu for forage production were April 20, May 1, May 15, and June 1; Peking produced the highest yield of forage when planted on May 1 and 15.

Both Manchu and Peking produced the highest yields of seed when planted April 15 to 20.

There appears to be no constant relation between forage yield and seed yield.

The effects of varying the rate of sowing are apparently not influenced by the date of sowing.

The tops of all the early plantings did not begin a vigorous development until about June 15th; consequently, the first four plantings of Manchu and the first two of Peking increased in weight of top growth almost as one planting after this date.

Low temperature is suggested as the most important factor causing this initial slow growth of the early plantings.

Manchu soybeans produced seed every year when planted August 1, though they did not always mature.

Peking soybeans produced seed every year when sown July 1, though they did not mature normally. In one year a small yield of seed was obtained from the August 1 planting.

Forage yields of both varieties decreased with each successive planting made after June 1, because of shorter season and the lack of soil moisture.

The soybean is a drouth-resistant crop only if well established before drouth comes.

The growing period of the varieties became progressively shorter with each later planting. In 1925 for each day's delay in planting, Manchu was delayed .395 days in ripening and Peking .215 days. In 1926 Manchu was delayed .343 days for each day in delay of planting and Peking .300 days.

Root-top ratio.—At Columbus the root-top ratio 2 weeks after emergence was about 1 : 2, and gradually increased until the end of the season when the final ratio was about 1 : 13 for the Manchu variety and 1 : 10 for Peking.

At Wooster, the average root-top ratio varied from 1 : 6 at the full bloom stage to 1 : 10 at the end of the season when the plants were mature.

Yields of plant parts. *Total tops.*—At Columbus, the maximum yields occurred at a stage when pods were formed and seed was forming (recorded September 10 for Manchu variety and September 20 for Peking).

At Wooster, the maximum yield of tops was obtained about September 15 and the stage of development varied for the different seasons.

At Columbus, Manchu yielded more total tops (hay) than Peking on all harvest dates up to September 10; with one exception, Peking outyielded Manchu when harvested after this date, the difference in favor of Peking being larger for the later sowings.

Leaves.—The maximum leaf yields of the Manchu variety were recorded on August 20 and Peking 11 days later (at the pod-forming stage).

At Wooster, the 6-year average yield of leaves reached a maximum about August 15 at stages of development ranging from "pods forming" to "small seed forming" and then decreased due to leaf fall and translocation of material from the leaves to the other plant parts.

The stem-leaf ratio.—At Columbus, 40 days after planting, the leaves comprised 70-80 per cent of the combined weight of leaves and stems; from this the percentage decreased to 60 just prior to leaf fall.

At Wooster, the 6-year average gave stem-leaf ratios of 1 : 2.48, 1 : 2.16, 1 : 1.79, 1 : 1.46, and 1 : .94 for the several harvests at 15-day intervals.

Stems.—In both studies maximum stem yields occurred during late August and early September.

At Wooster, the 6-year average shows a maximum yield of stems at the third date of harvest, whereas the leaves reached their maximum 15 days earlier. However, this occurred in only 3 years of the 6.

Pods.—The weight of pods increased rapidly until the seeds were about two-thirds formed; after this stage they either increased slowly, or, in some years, decreased.

Seed.—The increase in weight of seed per acre was very rapid, amounting to over 50 pounds per acre per day during the period of most rapid growth.

At Wooster, seed began to form about September 1 and was mature in about 30 days, at which time it made up 28.4 per cent of the total top yield.

Roots.—Both at Columbus and Wooster, the maximum root yield was reached about the time pod and seed formation began; August 20 to 30 at Columbus and September 1 at Wooster.

At Columbus, soil types were found to influence the development and extent of roots.

At Wooster, the 4-year average yield of roots increased from 391 pounds on about August 1 when the plants were in full bloom to a maximum of 550 pounds on about September 1 at the beginning of pod and seed formation, after which there was a decrease of 225 pounds by the time the seed was mature, October 1.

Nitrogen or crude protein (N x 6.25) in plant parts.—At Columbus, the content of protein in Manchu, as a 2-year average, decreased from 22 per cent early in July to 17.5 per cent early in August, after which date the percentage increased to 22.7 on September 22. The percentages for Peking were very nearly the same. A similar tendency was noted at Wooster.

The percentage of nitrogen in the leaves decreased about half as the plants matured; that in the stems to about ⅔ the initial percentage.

The percentage of nitrogen in the leaves was nearly twice as high as that of the stems.

The pods had a maximum nitrogen content of 3 to 4 per cent when the seed was beginning to form, which decreased to from 1 to 2 per cent at maturity. The nitrogen of the pods at the early stages of development was higher than in any other plant part.

The percentage of nitrogen in the seed apparently decreased slightly as the seed matured.

The percentage of nitrogen in the total tops decreased during the period of rapid growth and increased as the seed matured.

At Columbus, Manchu and Peking produced from 70 to 90 pounds per acre of nitrogen in the leaves and 30 to 35 pounds per acre in the stems. The maxima were reached in Manchu between August 15 and 20, and in Peking about 10 days later. At these dates pods were forming.

At Wooster, as a 6-year average, the maximum amount of nitrogen in the leaves, nearly 70 pounds per acre, occurred about August 15 at the beginning of pod formation, while that in the stems, 21 pounds, was recorded 15 days later.

The nitrogen per acre in the pods in all studies both at Columbus and Wooster reached a maximum about 10 days later than that in the leaves.

The nitrogen per acre in total tops of Manchu at Columbus and in the varieties studied at Wooster reached a maximum early in September and in Peking at Columbus about 10 days later, at a time just prior to normal leaf fall.

More than half of the nitrogen in the total tops was stored in the seed at maturity.

The maximum amount of nitrogen per acre in the roots, 12 pounds at Columbus and 9.4 pounds at Wooster, was recorded about August 15, after which time it decreased to about half these amounts at maturity.

At Wooster, as an average of 4 years, the tops contained ten times as much nitrogen per acre as the roots on August 1 and increased to 23 times as much at maturity.

Phosphorus in plant parts.—The total tops contained about .3 per cent phosphorus in both experiments and changed but little with different dates of harvest. However, there is some indication of an increase in percentage at maturity.

The content of phosphorus in the leaves decreased as the plant approached maturity.

The content of phosphorus in the stems also decreased at about the same rate at both Columbus and Wooster, from about .26 to .10 per cent.

At maturity the seeds contained about .75 per cent phosphorus or about 4 times that of the leaves, stems, and pods.

The pounds per acre of phosphorus in the pods increased until the beginning of seed formation and then decreased. This decrease indicates a movement of phosphorus from the pods into the seeds.

Potassium in plant parts.—At Wooster, the percentage of potassium in the total tops decreased slightly following the full bloom stage and increased again at the end of the season. The total amount of potassium per acre in the tops increased as the plants approached maturity. Leaf fall resulted in a loss in some seasons.

The leaves and stems decreased in percentage of potassium as the plants approached maturity. The storage of potassium in the leaves reached a maximum in the early stage of pod formation and then decreased. The storage in the stems showed a decrease somewhat later than that in the leaves, about the time of rapid seed formation.

The percentage of potassium in the pods was relatively higher than that in the leaves and stems and decreased rapidly as the seed developed.

Potassium in the mature seed was relatively higher both in percentage and amount per acre than in other plant parts. There was some indication that the percentage of potassium in the seed decreased slightly in the final stages of ripening.

There was apparently a slight decrease in the potassium content of the roots as maturity approached.

Calcium in plant parts.—The data as a whole indicate a decrease in percentage of calcium in the total tops as the plants approached maturity. The leaves contained a higher percentage of calcium than other plant parts. The maximum amount of calcium per acre in total tops was obtained about September 1, and was followed by a decrease probably caused largely by leaf fall.

The percentage of calcium in the plant parts was highest in the leaves, followed in order by pods, stems, roots, and seeds.

There is some indication of a storage of calcium in the stems, followed by a movement into the pods, where it accumulated toward the end of the season.

Magnesium in plant parts.—The percentages and amounts of magnesium and calcium were similar in the stems. However, magnesium was slightly higher in the roots and seeds. In the leaves and pods, the percentage and amount of magnesium was much lower than that of calcium.

Removal and return of fertility constituents.—The amounts of nitrogen and mineral matter removed from and returned to the soil by the soybean crop under various methods of utilization, as calculated from the Wooster data, were discussed in Part II.

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